Evaluating LiDAR Applications for Forest Vegetation Management

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OUTLINE

- Background - A primer on LiDAR
- Applications for forest inventory and vegetation management
- Habitat Mapping for the American marten (*Martes americana)*
- Mapping slopes, soils, and terrain-related data
- Strategies for making LiDAR data products accessible and available for field work with AGOL

A PRIMER ON LIDAR

A PRIMER ON LIDAR

LiDAR
(Light Detection and Ranging)

- *Active sensor* - laser sends out light and sensor measures the time it takes for light to return
- Penetrates forest canopy
- Ideal for mapping forest density and canopy layers
- Ideal for mapping large areas (1000's to tens of 1000's of acres)

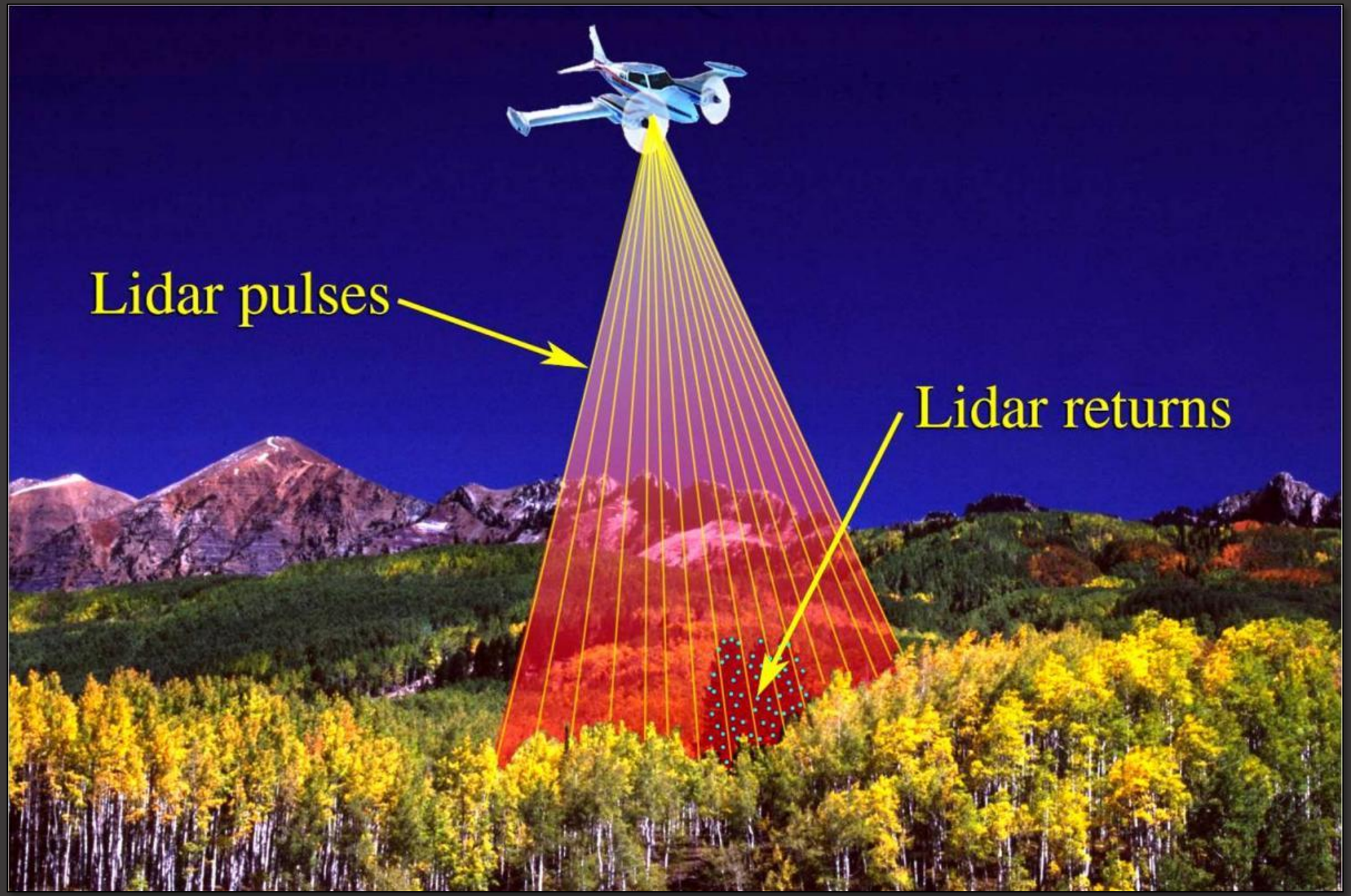
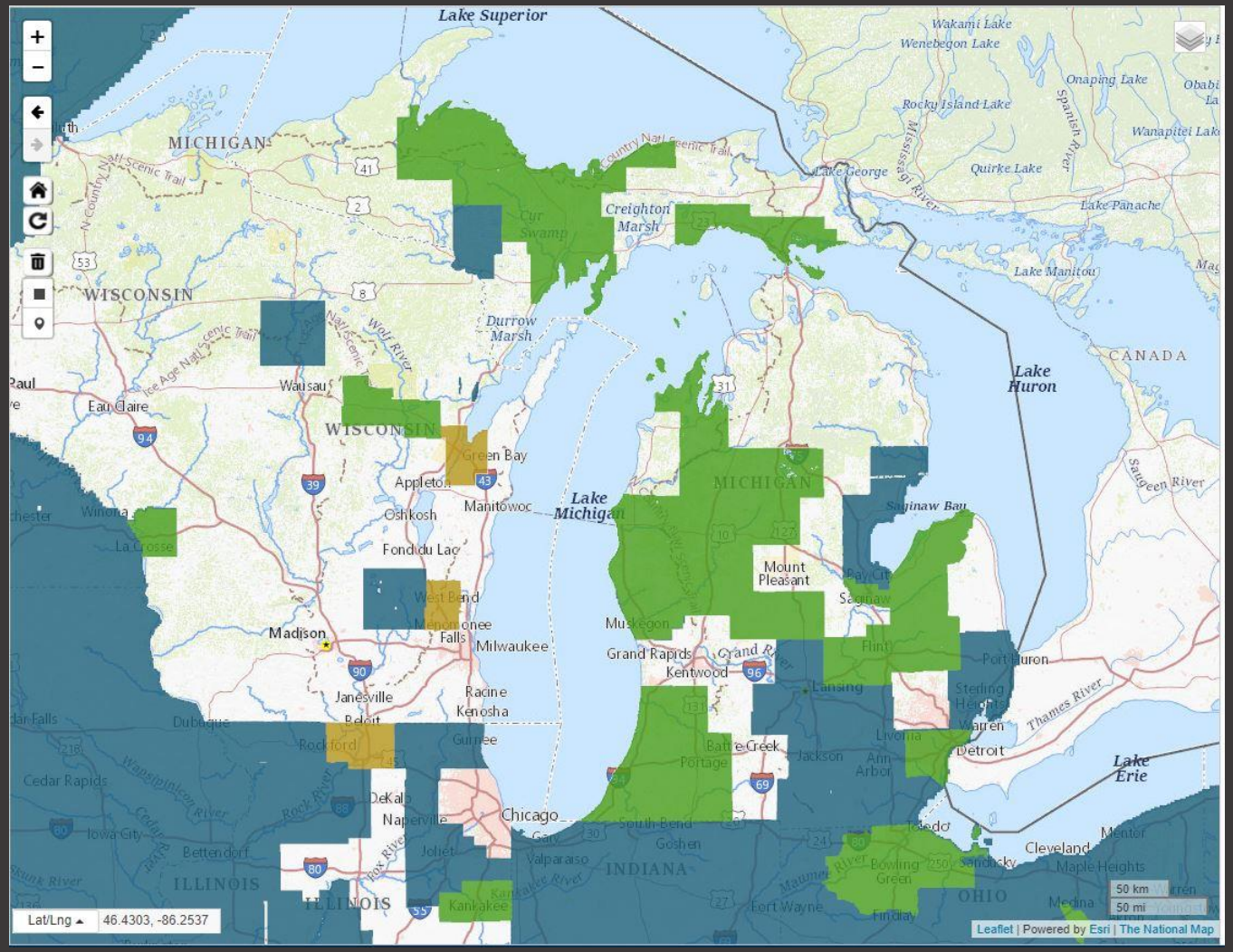


Image from VCGI Lidar http://vcgi.vermont.gov/lidar

LIDAR AVAILABILITY IN REGION 9

https://viewer.nationalmap.gov/basic/



Availability

- Several County and state datasets have been released to the public in recent months
- Available via FTP download, stored in tiles

LiDAR Quality Levels

Level 1 – Highest resolution (8 points/m^2)

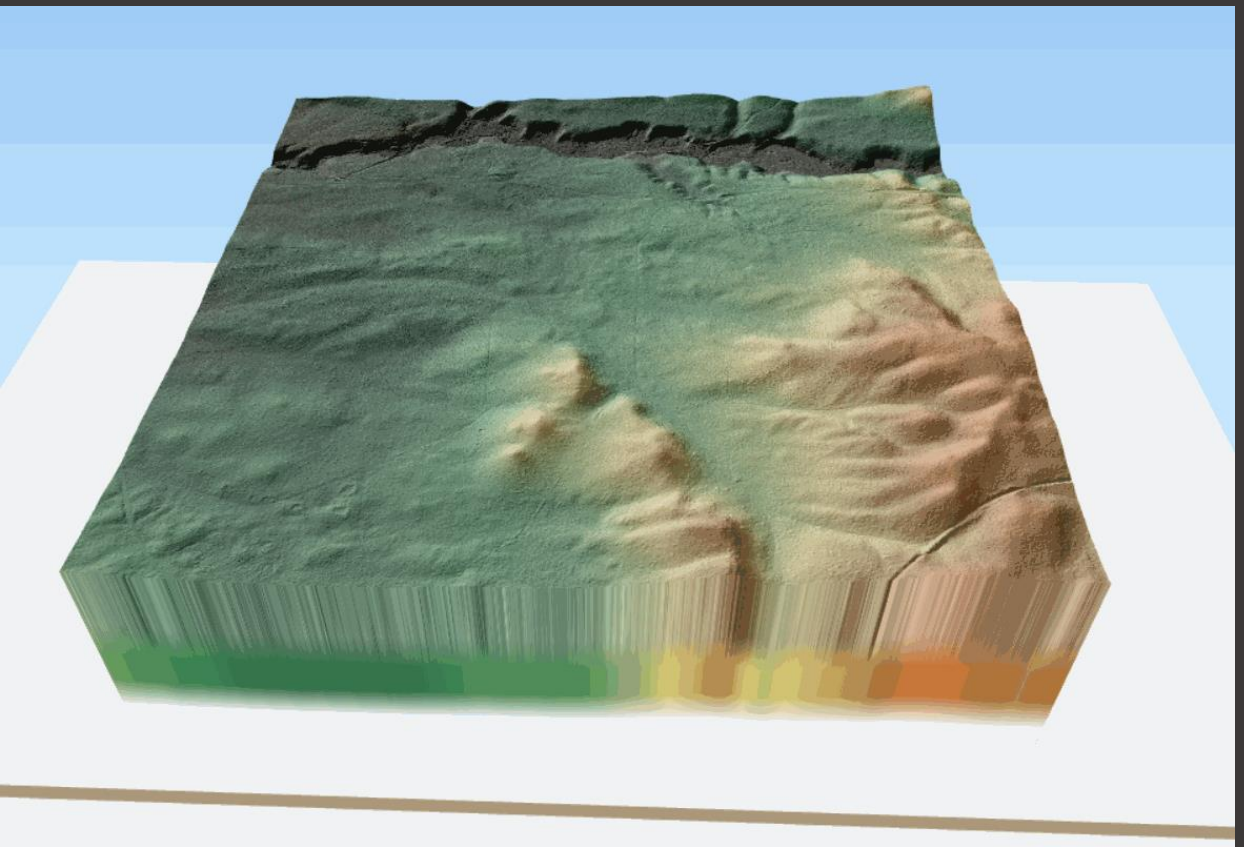
Level 2 – Moderate resolution (2 points/m^2)

Level 3 – Low resolution (0.5 points/m^2)

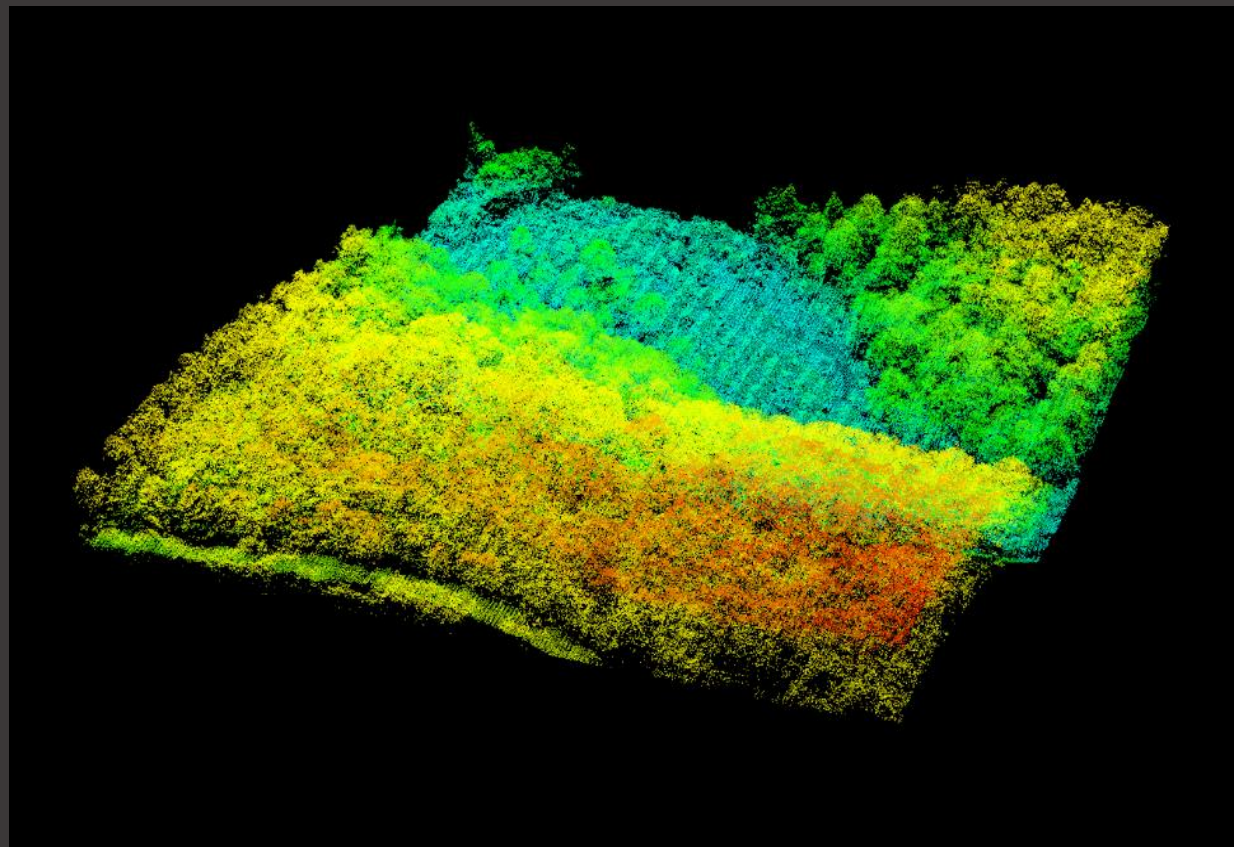
A PRIMER ON LIDAR

(Two main types of data delivered from LiDAR)

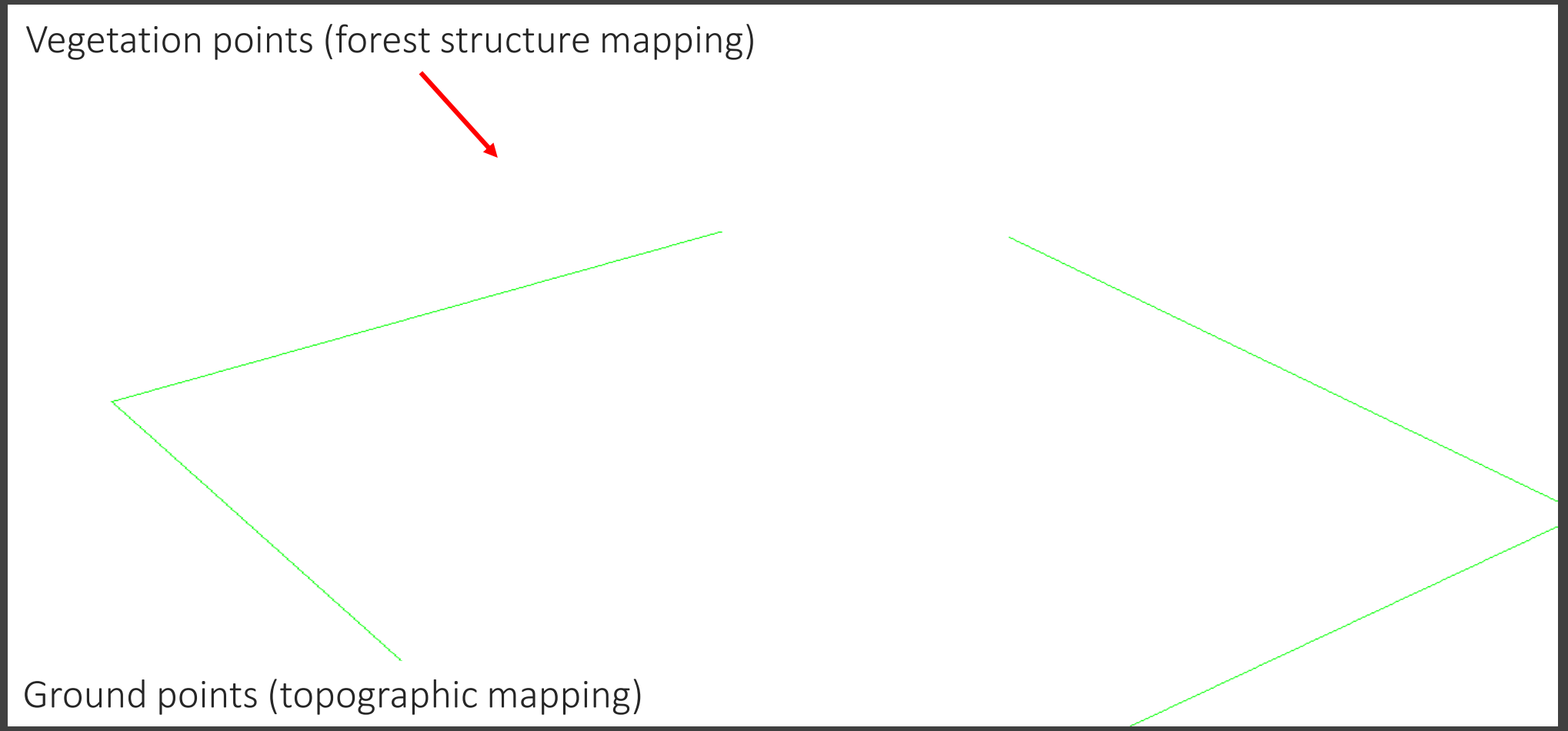
Digital Elevation Model



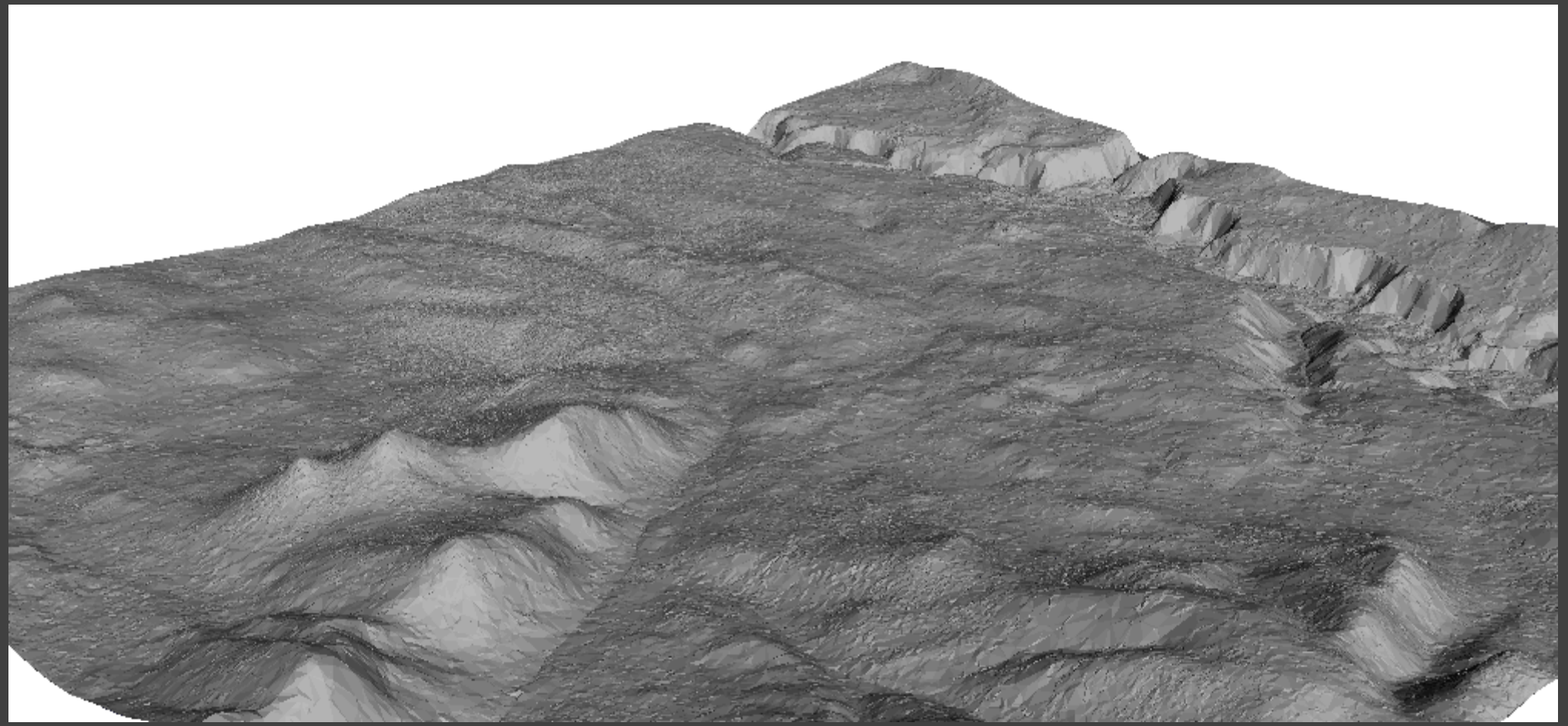
Point Cloud



A PRIMER ON LIDAR



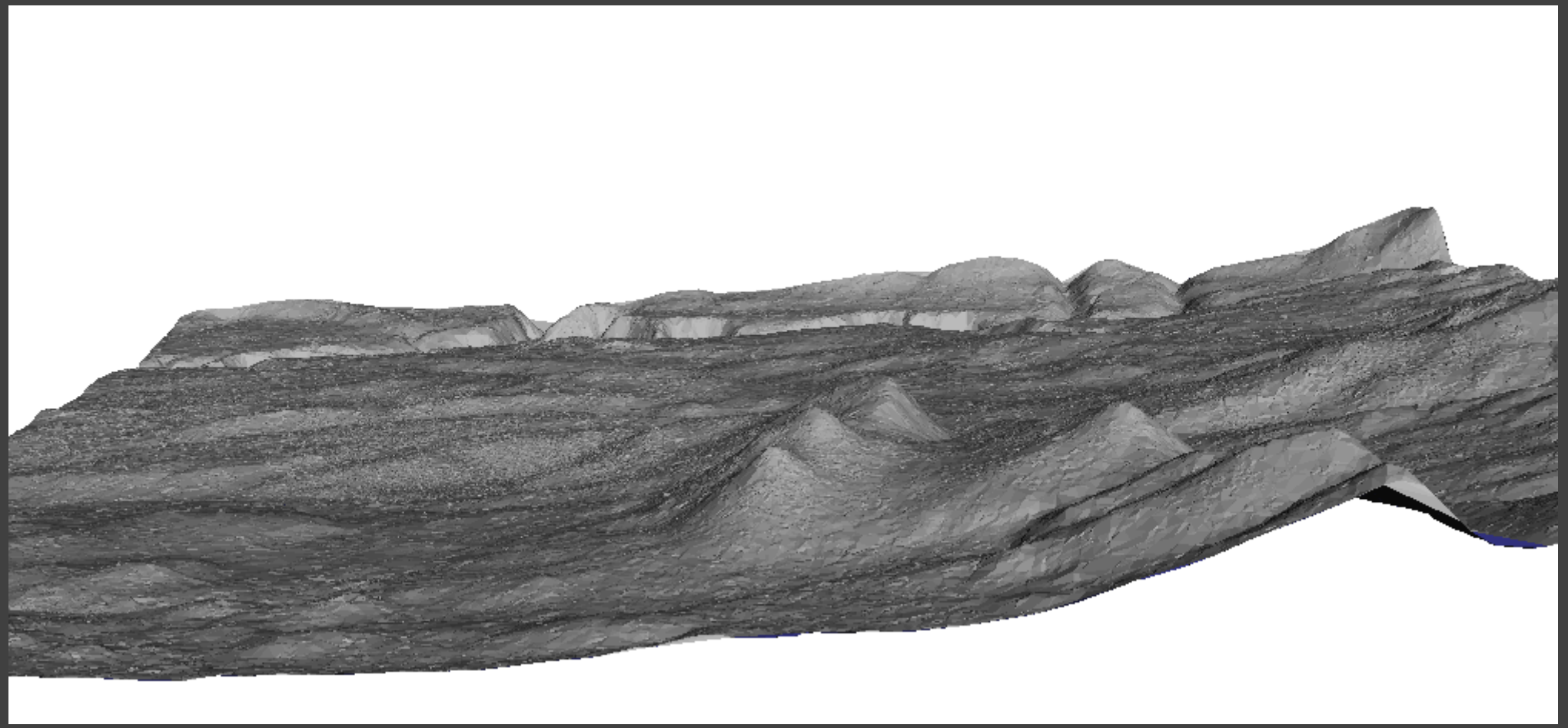
Each point contains a number of different attributes…



Terrain model with point cloud colored by

Classification

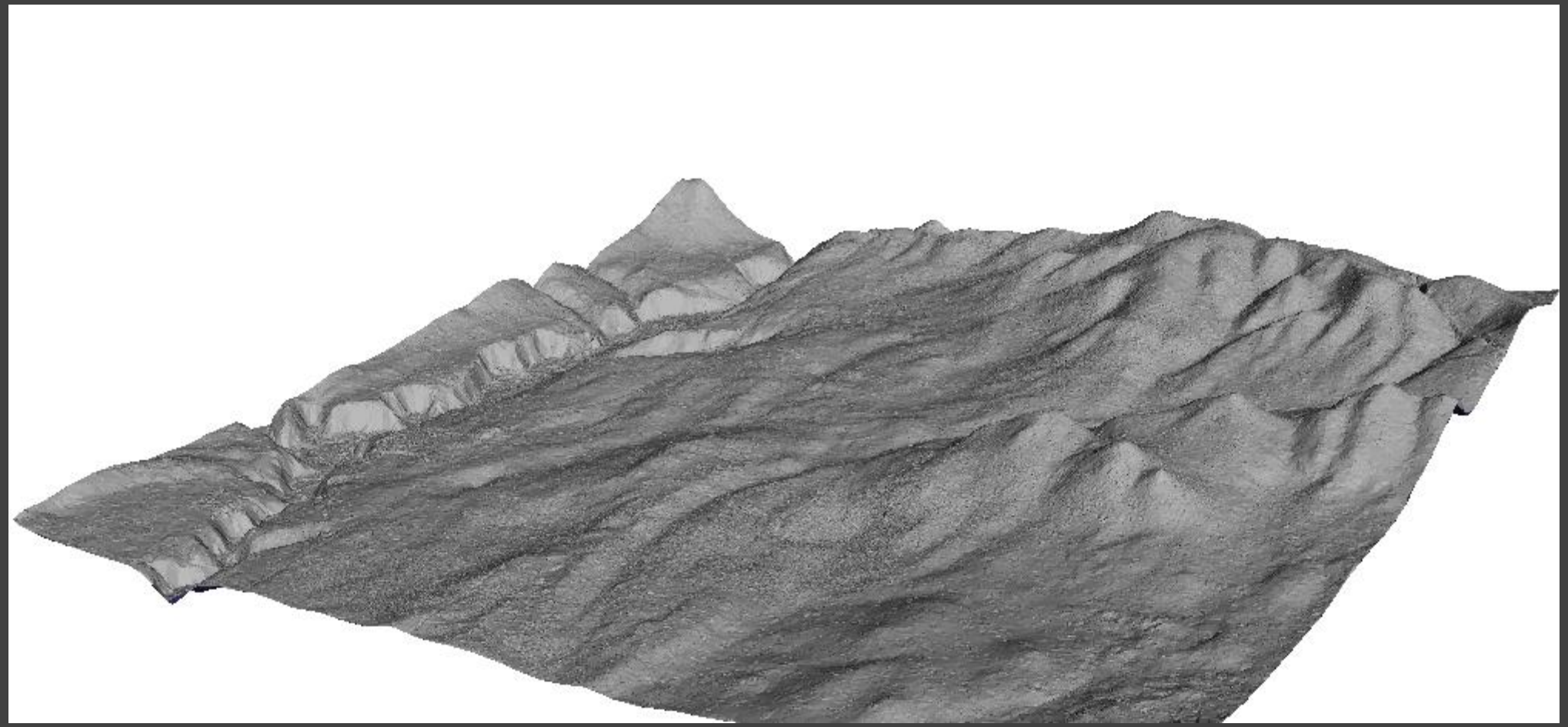
Each point contains a number of different attributes…



Terrain model with point cloud colored by

Elevation

Each point contains a number of different attributes…



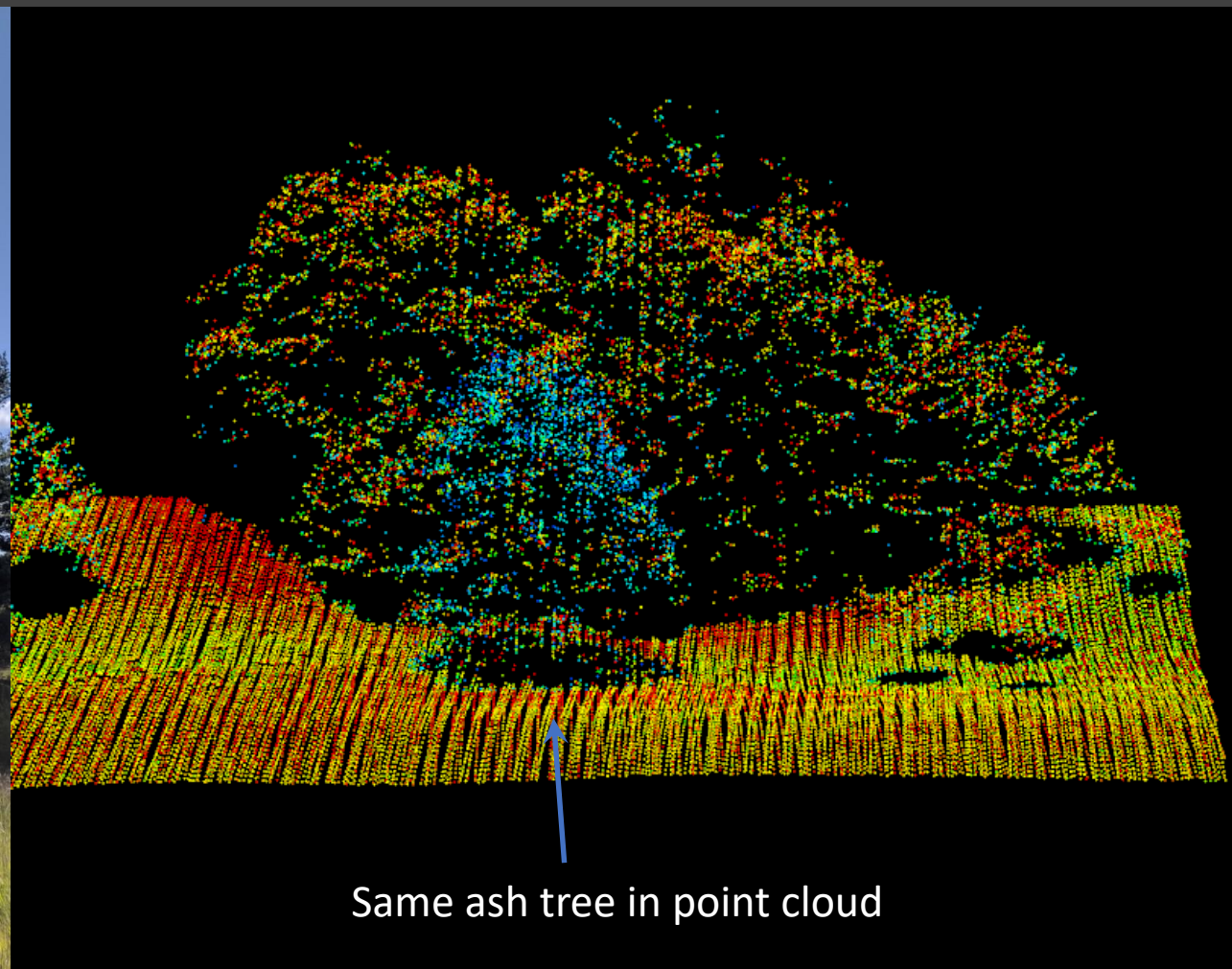
Terrain model with point cloud colored by

Intensity

INTERPRETING THE “POINT CLOUD”…

Real life vs. point cloud (colored by intensity)

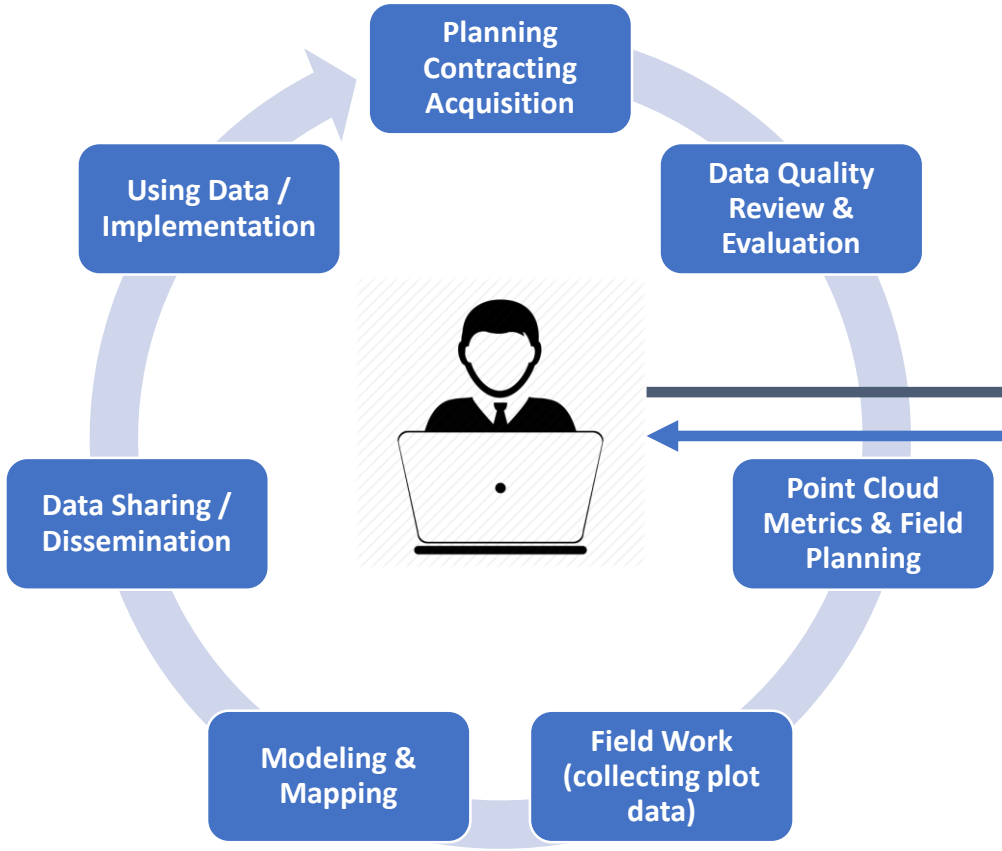
Dead ash tree in foreground

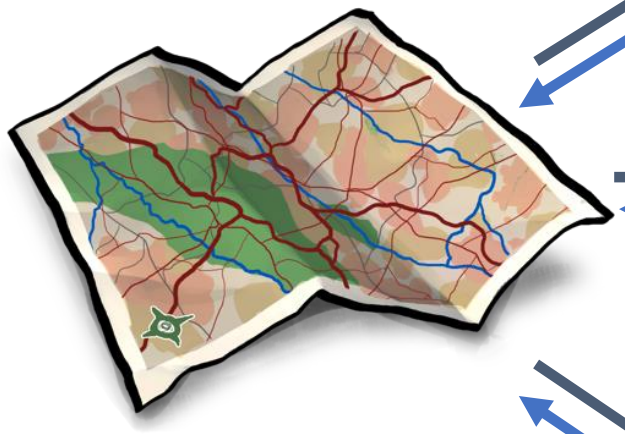


Same ash tree in point cloud

People who understand how to work with raw LiDAR Data, and…

Making a LiDAR project work for your organization is a team effort!





…People who understand the natural resource (and know what questions to ask of the data)

APPLICATIONS FOR FOREST INVENTORY AND MAPPING

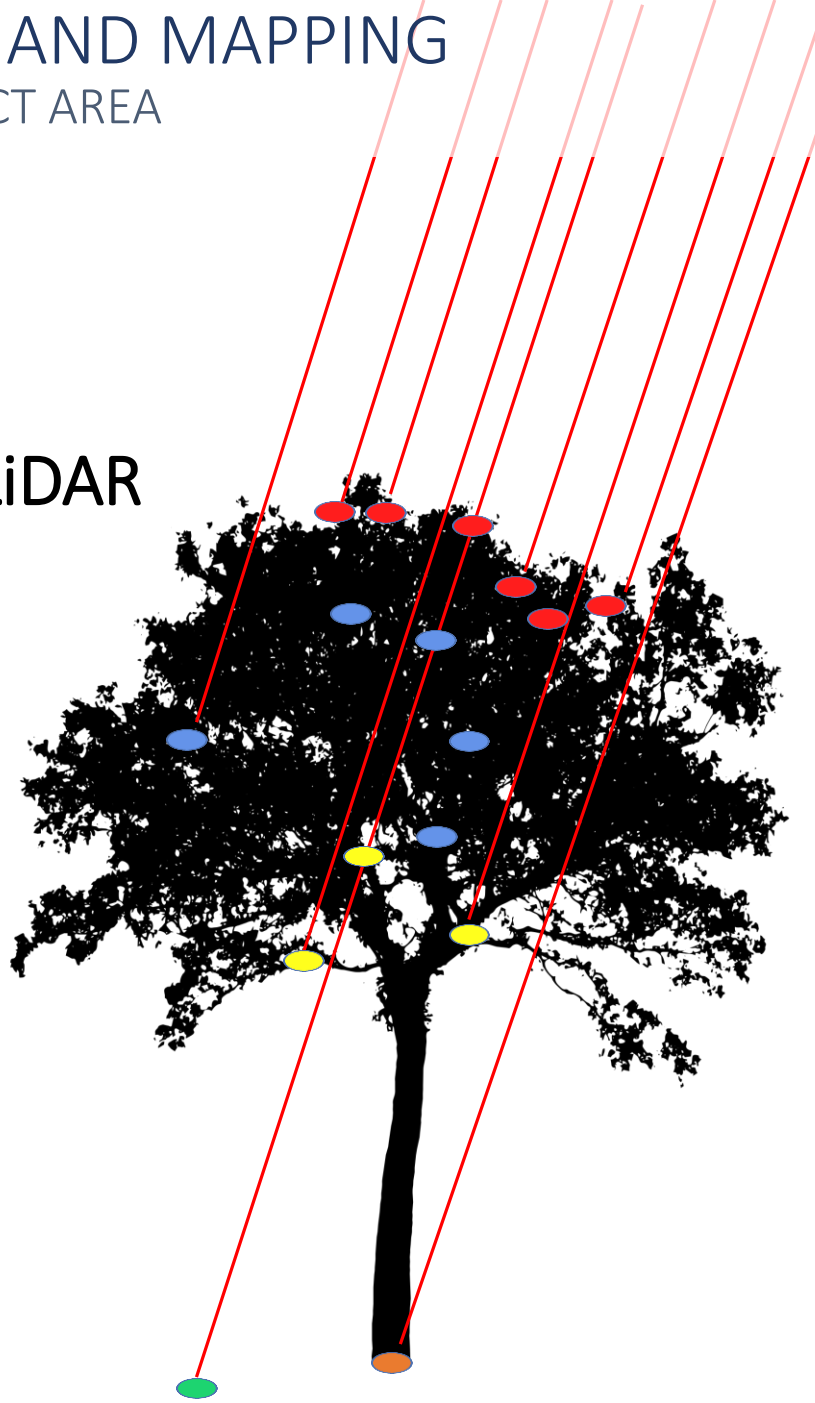
LIDAR DATA FROM THE OLGA LAKE PROJECT AREA

APPLICATIONS FOR FOREST INVENTORY AND MAPPING

LIDAR DATA FROM THE OLGA LAKE PROJECT AREA

Some possible forest inventory data products using LiDAR

- Canopy height / Canopy Hillshade
- Canopy cover
- Forest Inventory Metrics
- Tree segmentation
- Standing Dead Trees
- Conifer/Deciduous Mapping

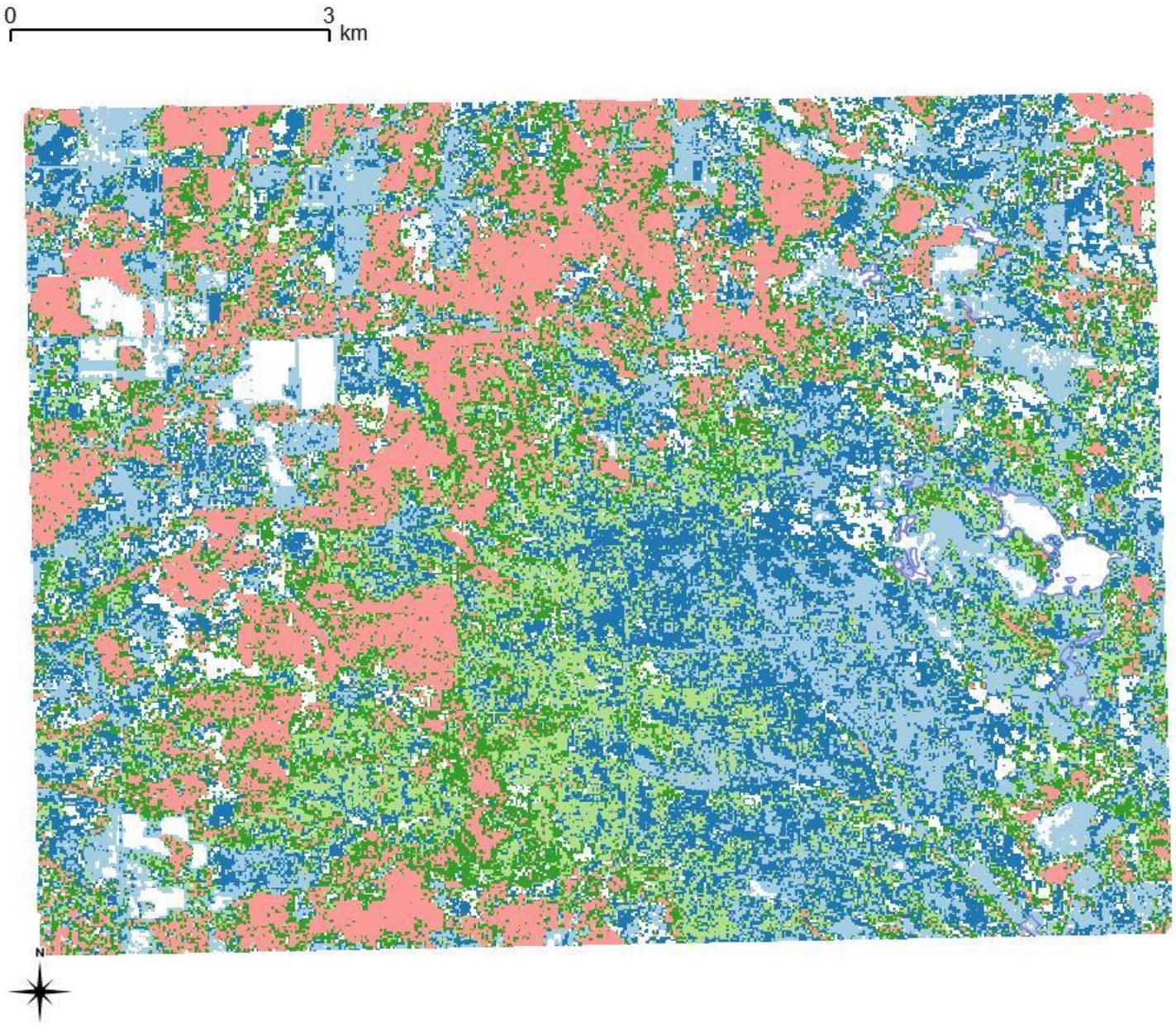


DATA PROCESSING – LANDSCAPE STRATIFICATION

Stratified Random Sampling
Divide the project area into areas of similar height and density

9 classes total

5 sample plots in each



DATA PROCESSING – LANDSCAPE STRATIFICATION

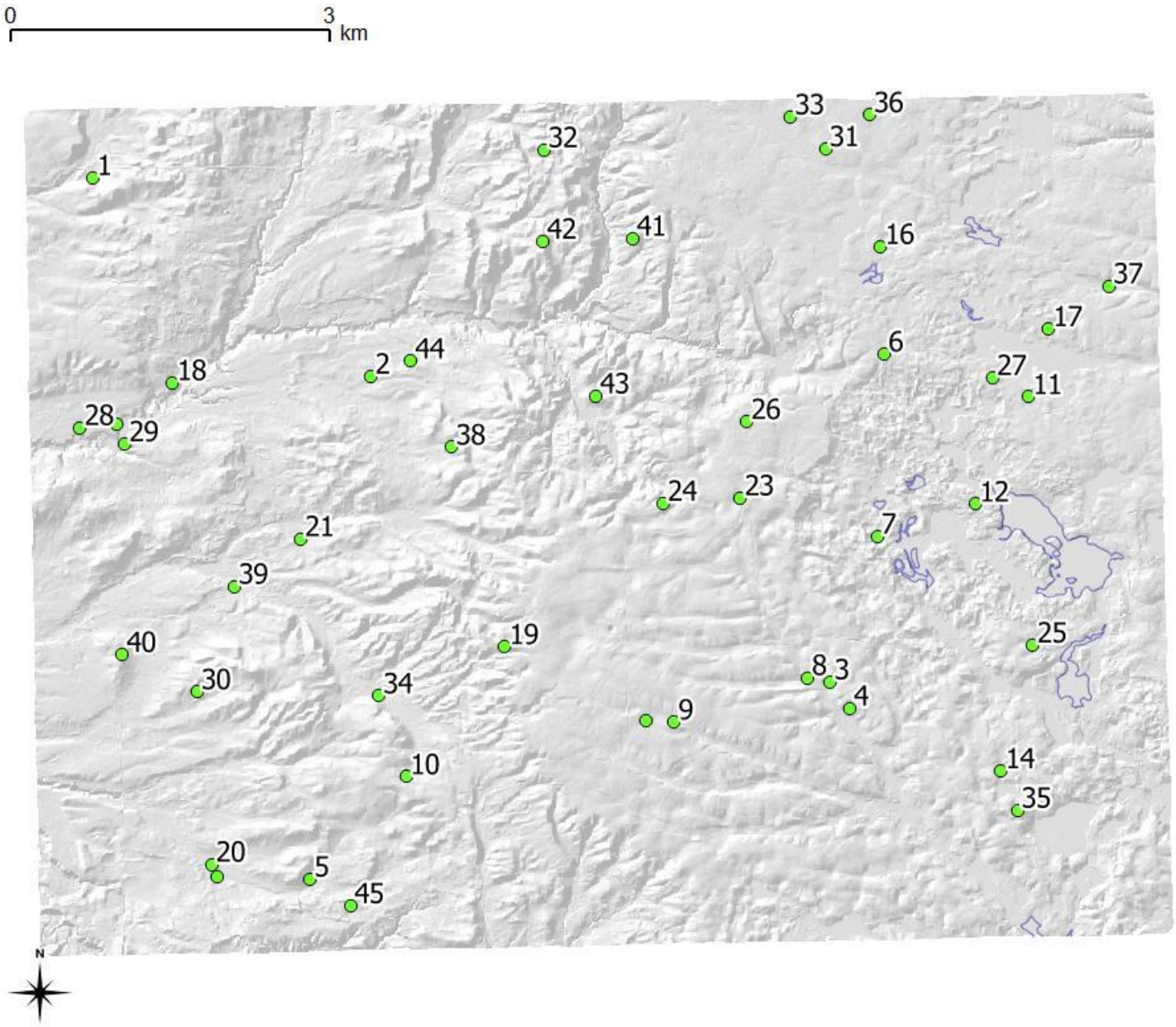
Stratified Random Sampling

Divide the project area into areas of similar height and density

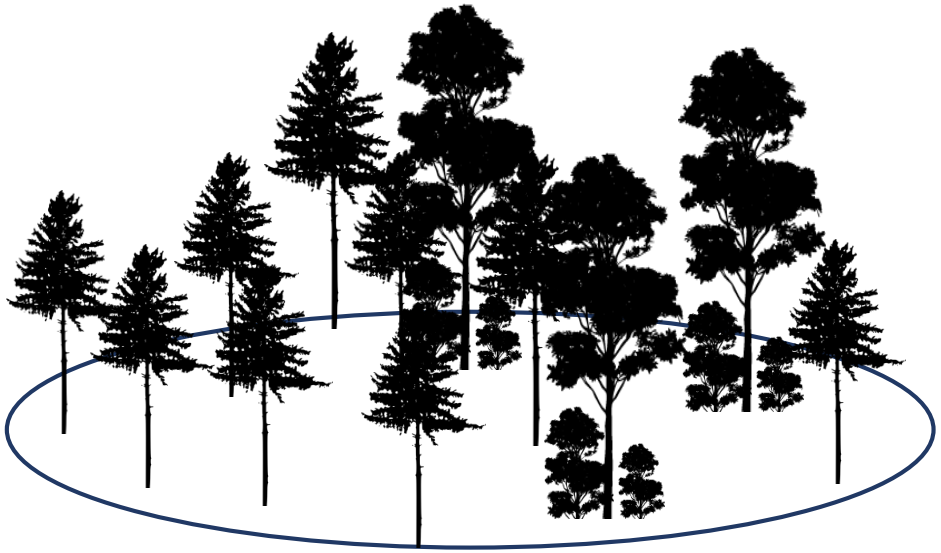
9 classes total

5 sample plots in each

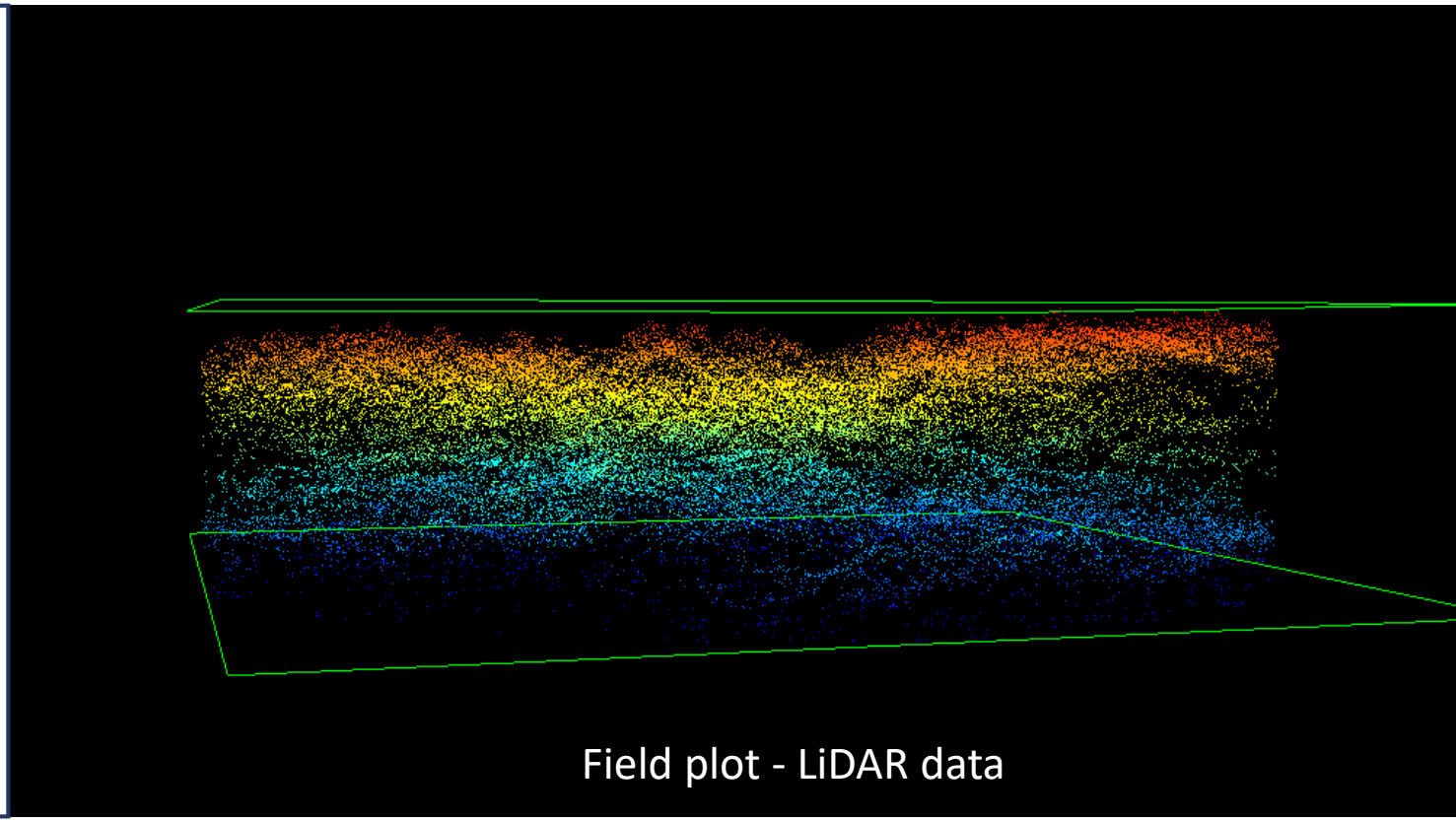
(45 field plots)



Forest-Wide Inventories with corresponding plot analysis…



Field plot – tree measurements



Field plot - LiDAR data

1. Measure all trees in a plot…
2. Extract the LiDAR point cloud from the same plot
3. Repeat for several plots across the area
4. Develop statistical models that relate the point cloud to the field measurements
5. Apply model to the whole area!

FOREST-WIDE INVENTORY WITH AREA BASED APPROACH

By laying out a series of ground plots across the LiDAR footprint, a wide variety of inventory metrics can be modeled…

<u>Example Products Include</u>

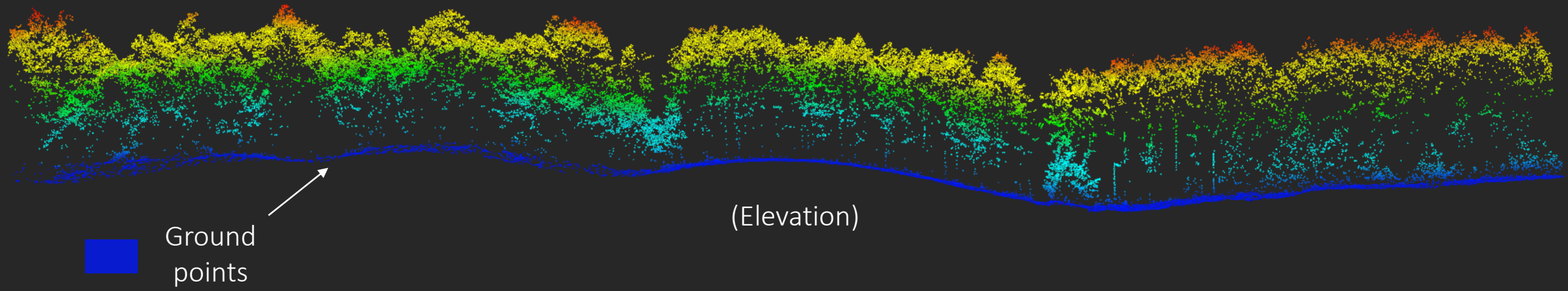
Basal Area
Merchantable Volume
Quadratic Mean Diameter
Lorey's Height
Trees Per Acre

Tree Height (meters)

High: 28

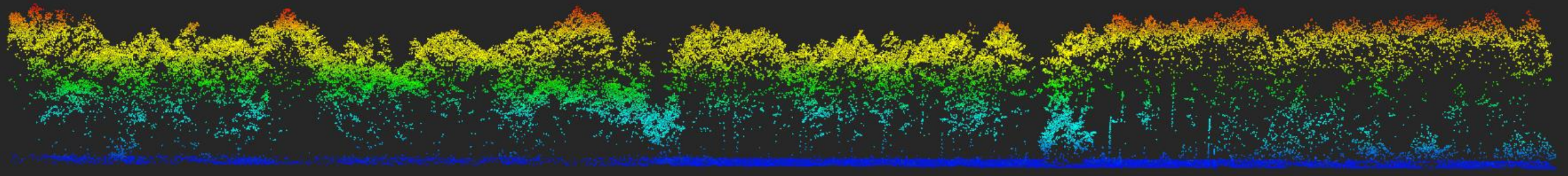
Low:0

LiDAR Point Cloud Cross Section illustrating the difference between elevation and height

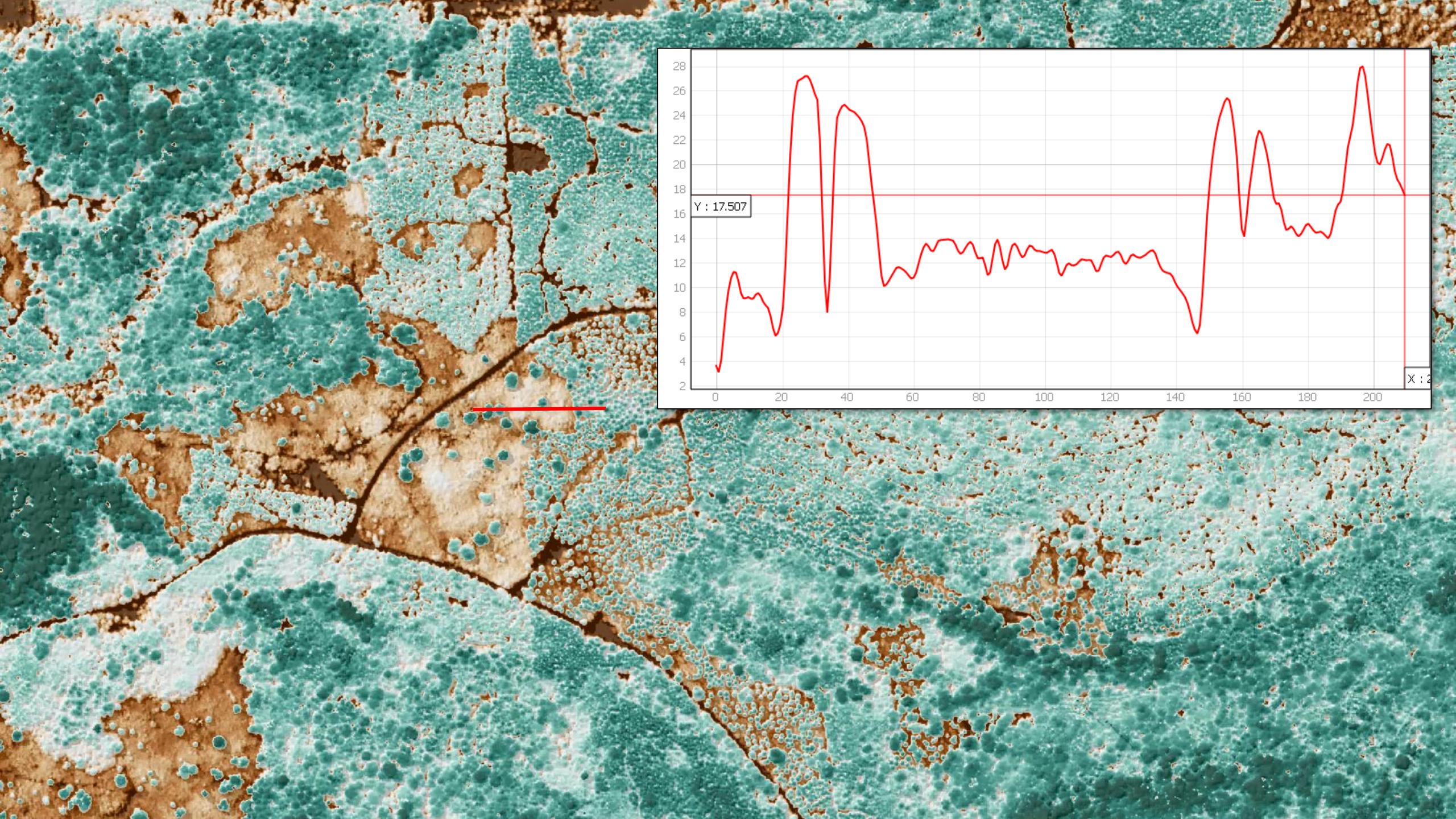


Ground points

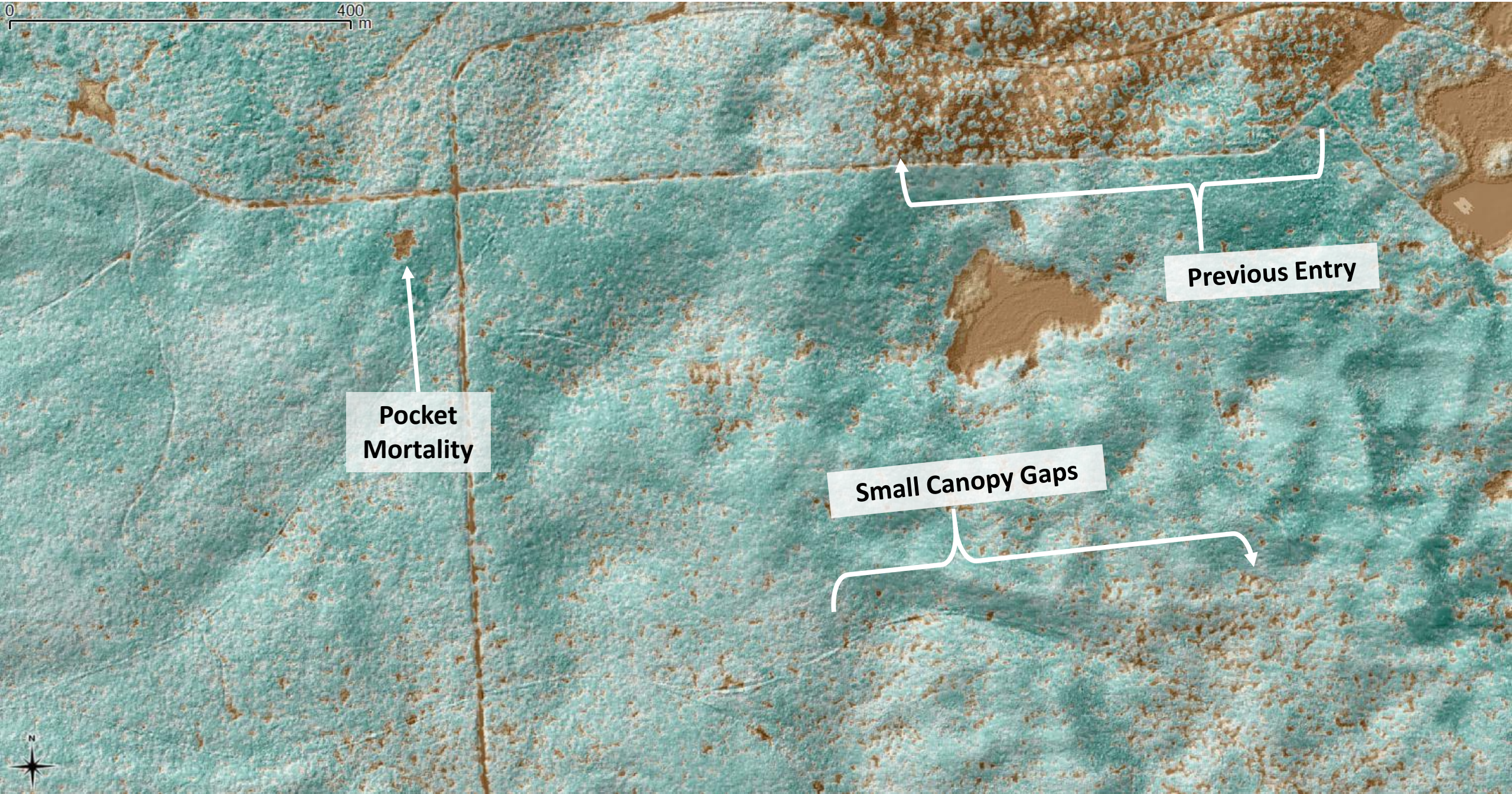
(Elevation)



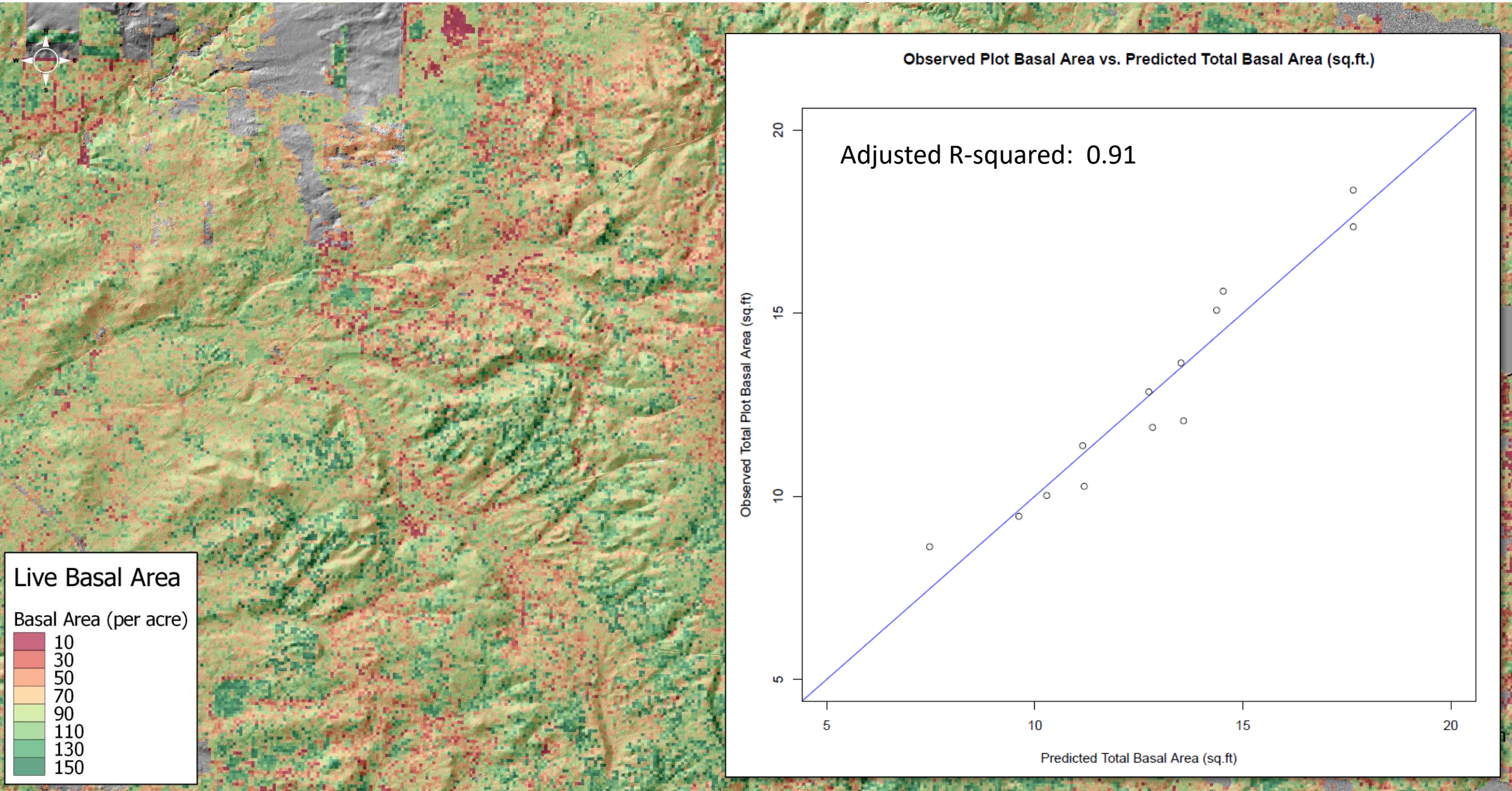
(Height)

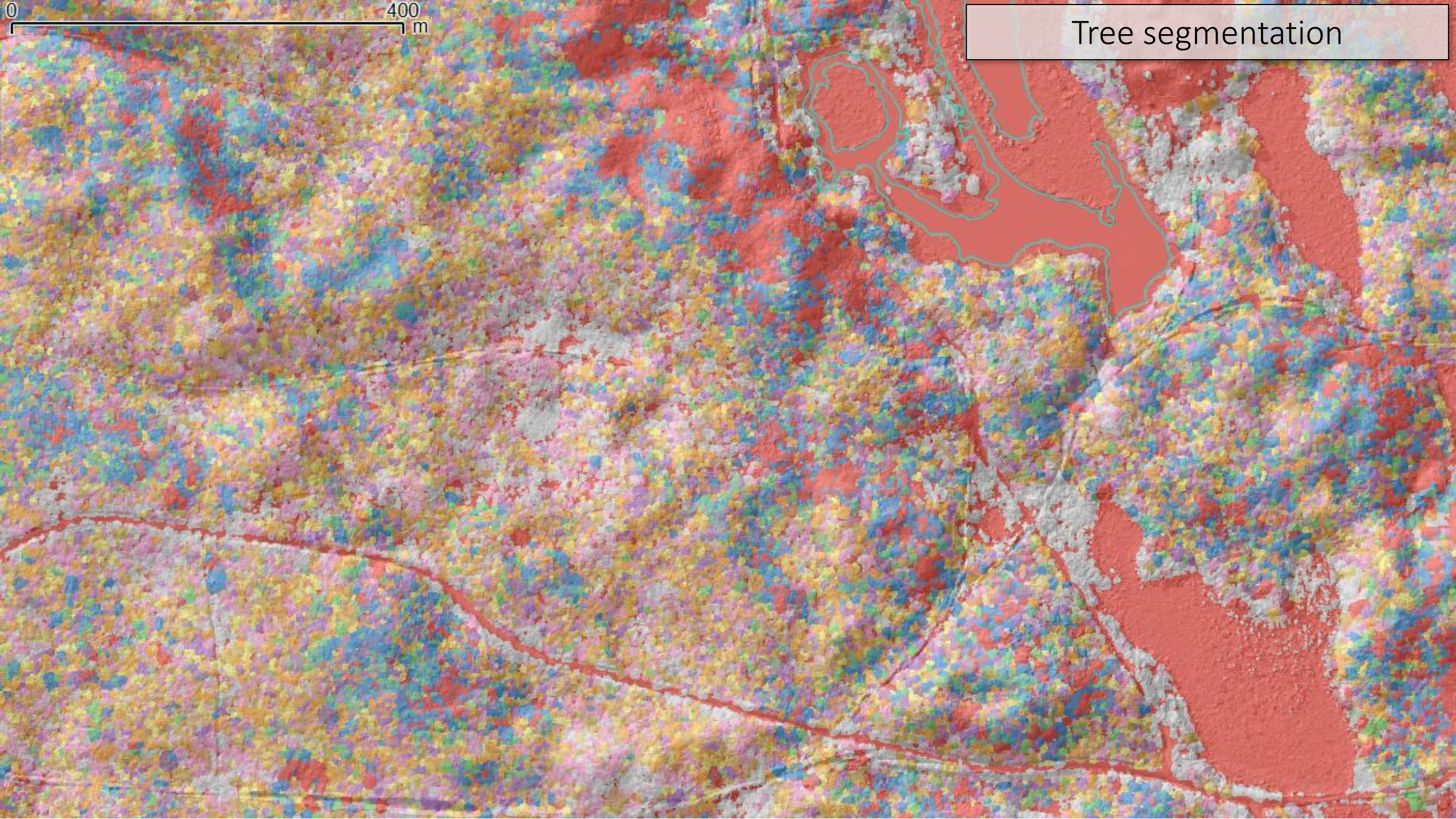

28
26
24
22
20
18
16
14
12
10
8
6
4
2
Y : 17.507
0
20
40
60
80
100
120
140
160
180
200
X : 2

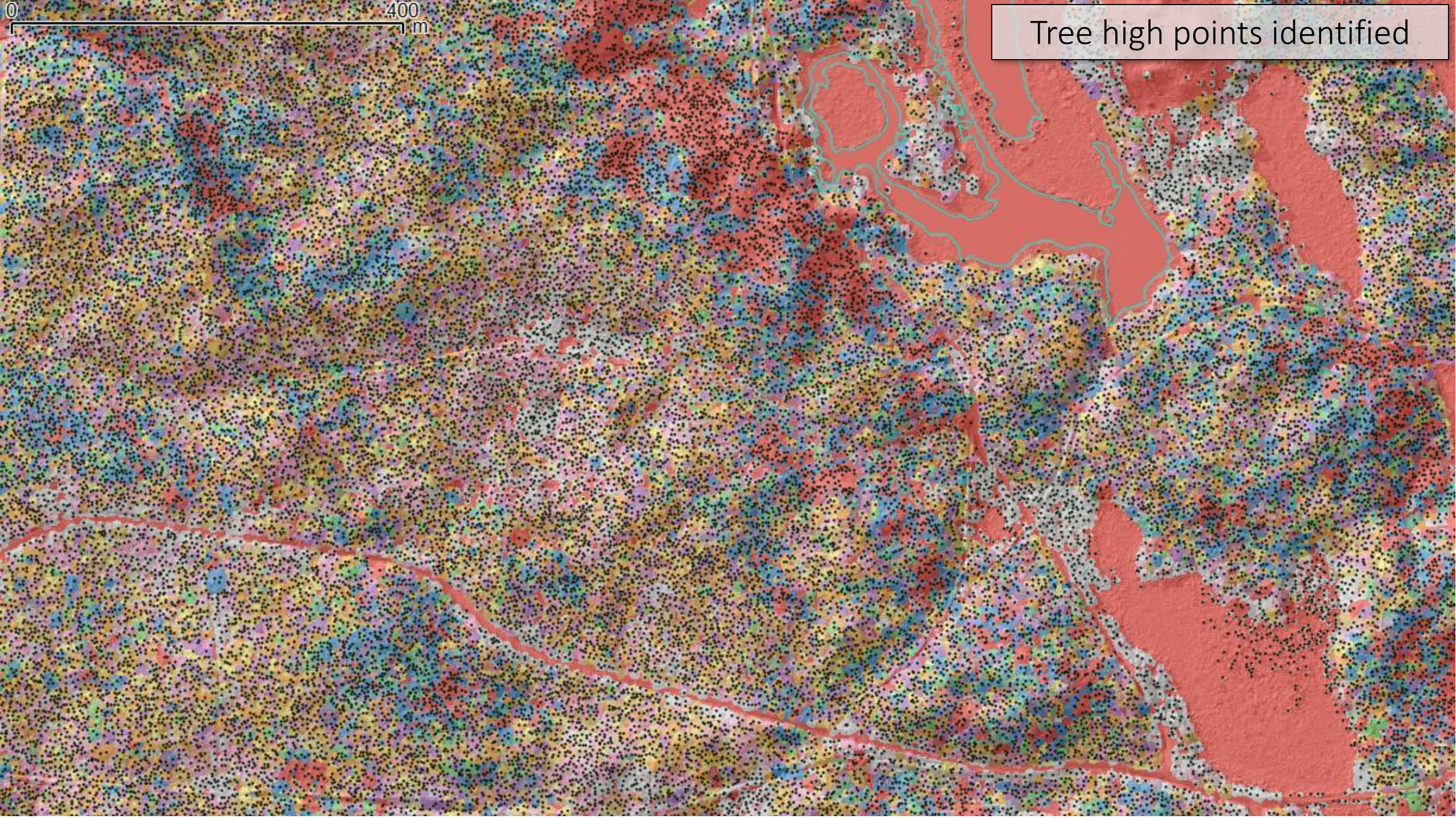
Canopy Height Map with Semi-Transparent Hillshade



Mapping Basal Area Acre Across Wide Areas

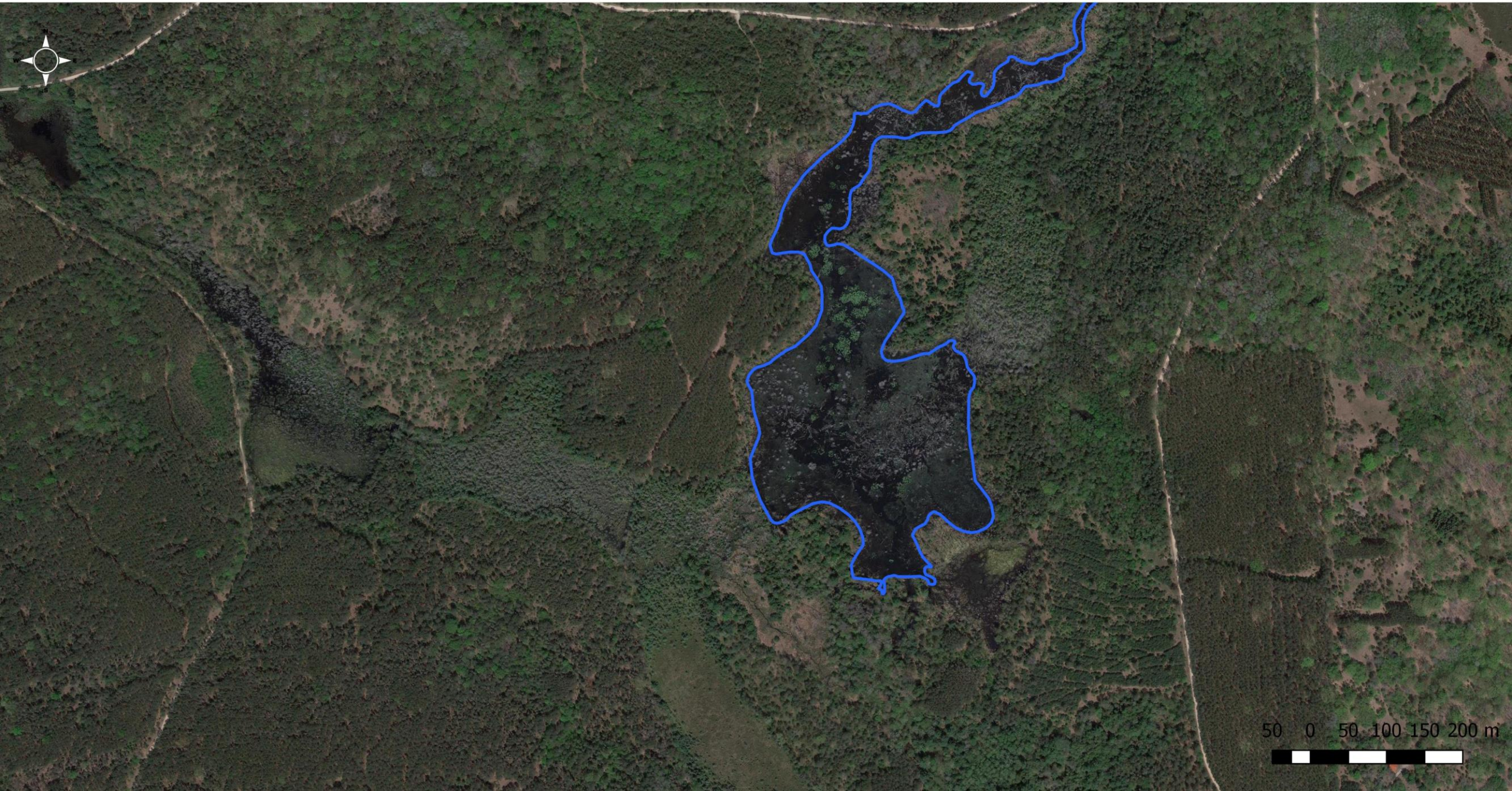



0
400
m
Tree segmentation


0
400
m
Tree high points identified

Mapping Trees per Acre Across Wide Areas

Mapping Standing Dead Trees Using LiDAR Intensity Data

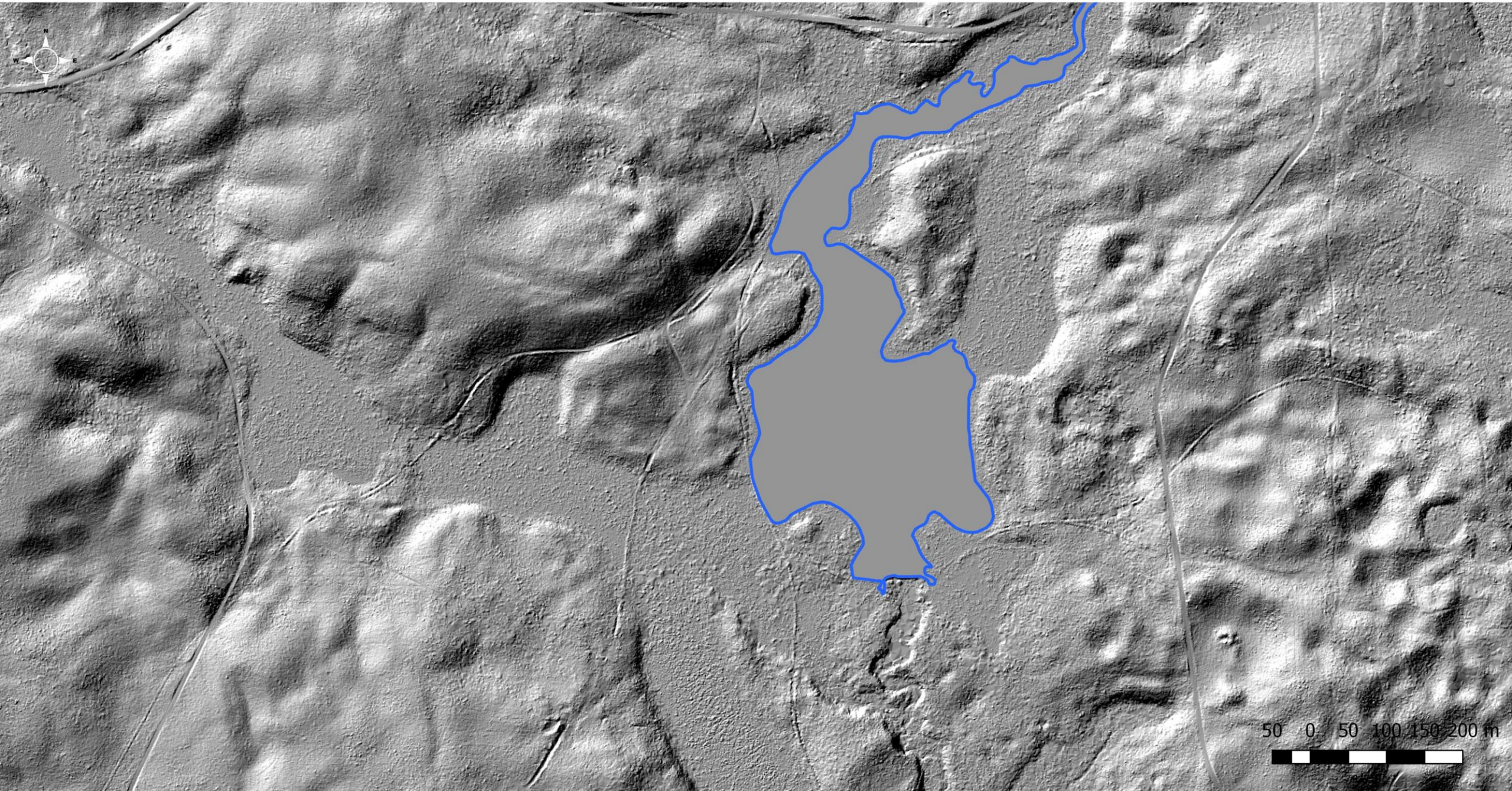


Many wetlands have standing dead trees, which make for a good “training” sample to identify other standing dead trees.

Potential applications:

- Habitat (Snag density)
- Disease Inventory (Ash Trees)

Mapping Standing Dead Trees Using LiDAR Intensity Data



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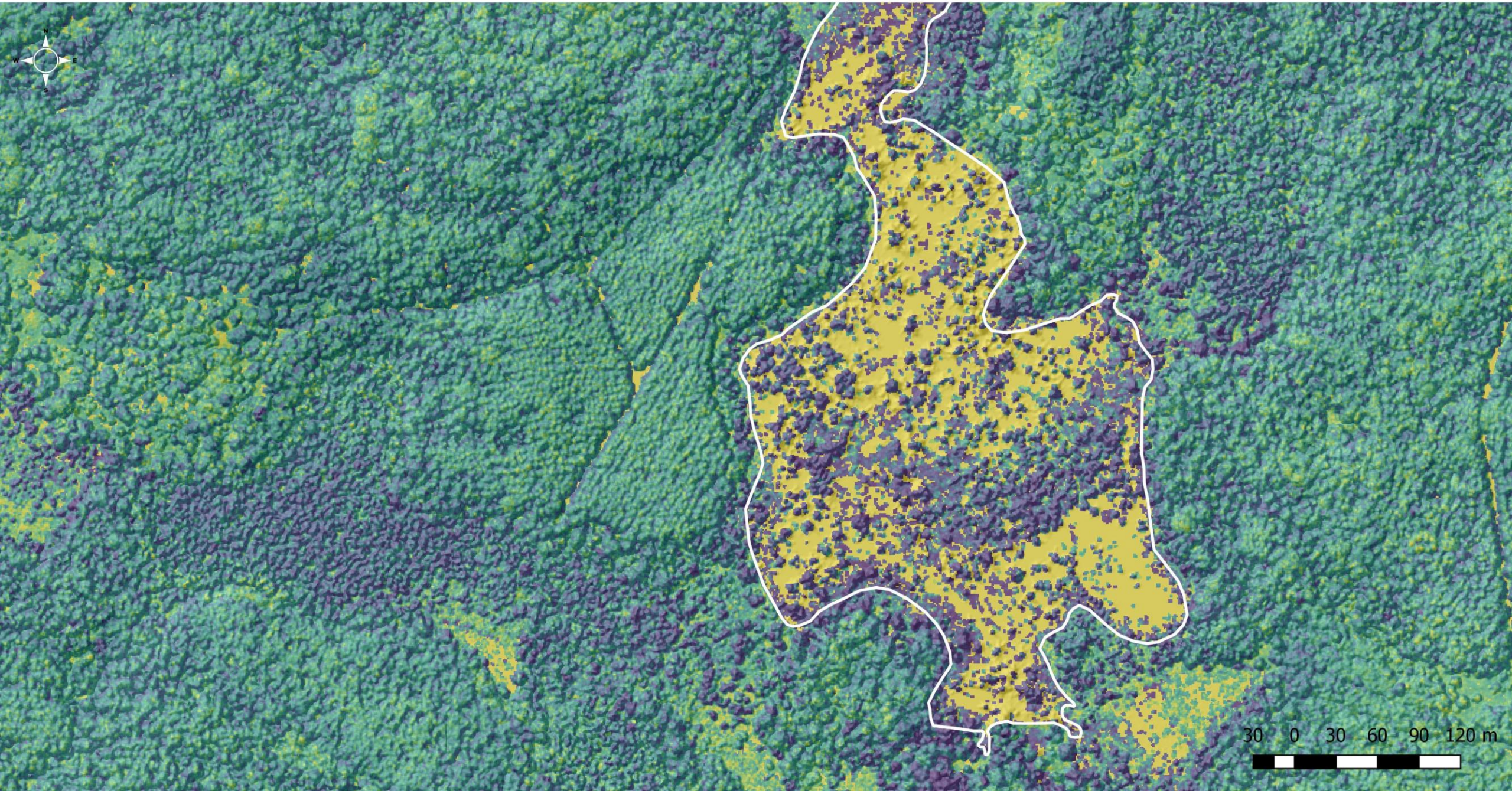

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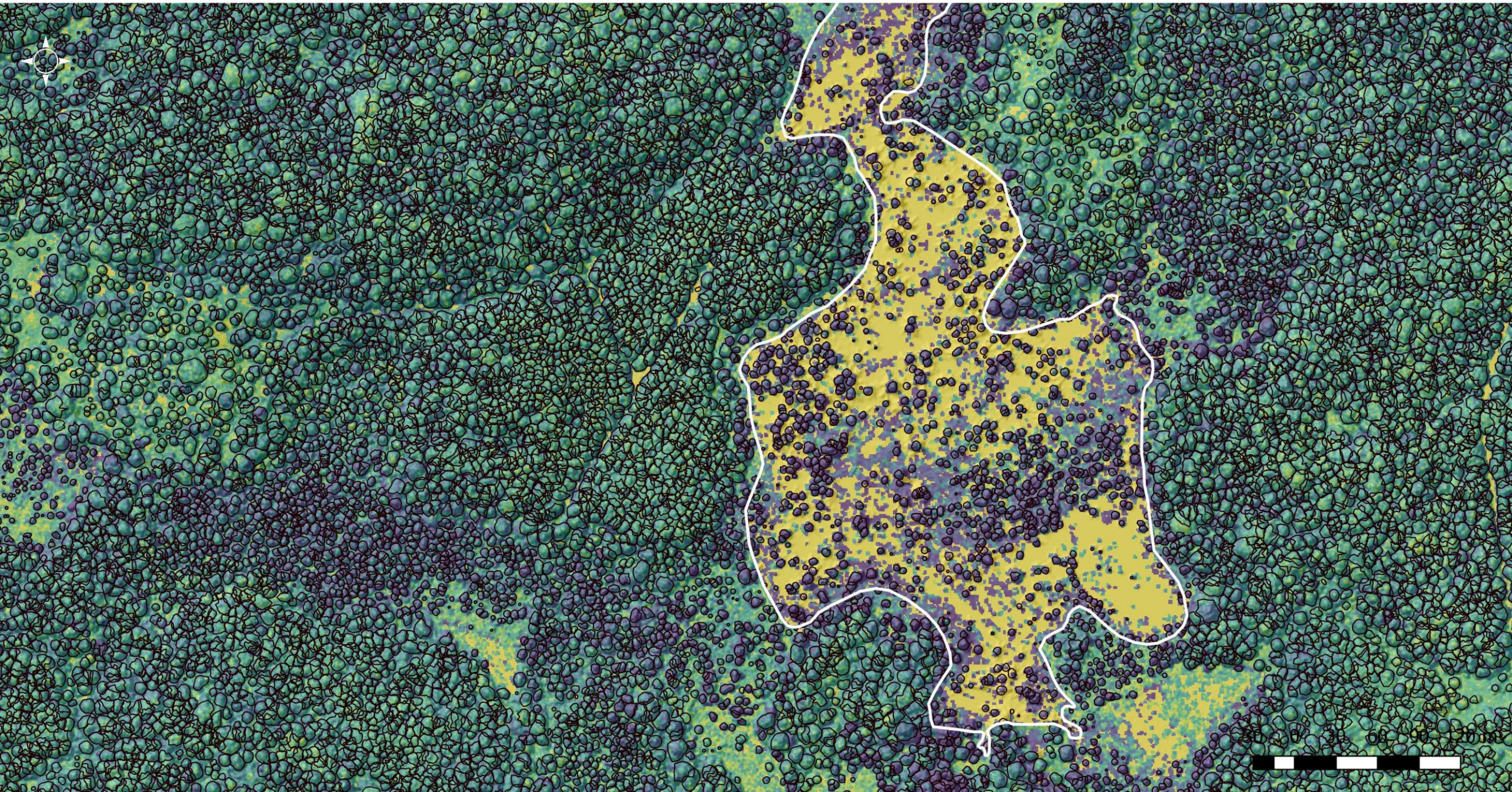

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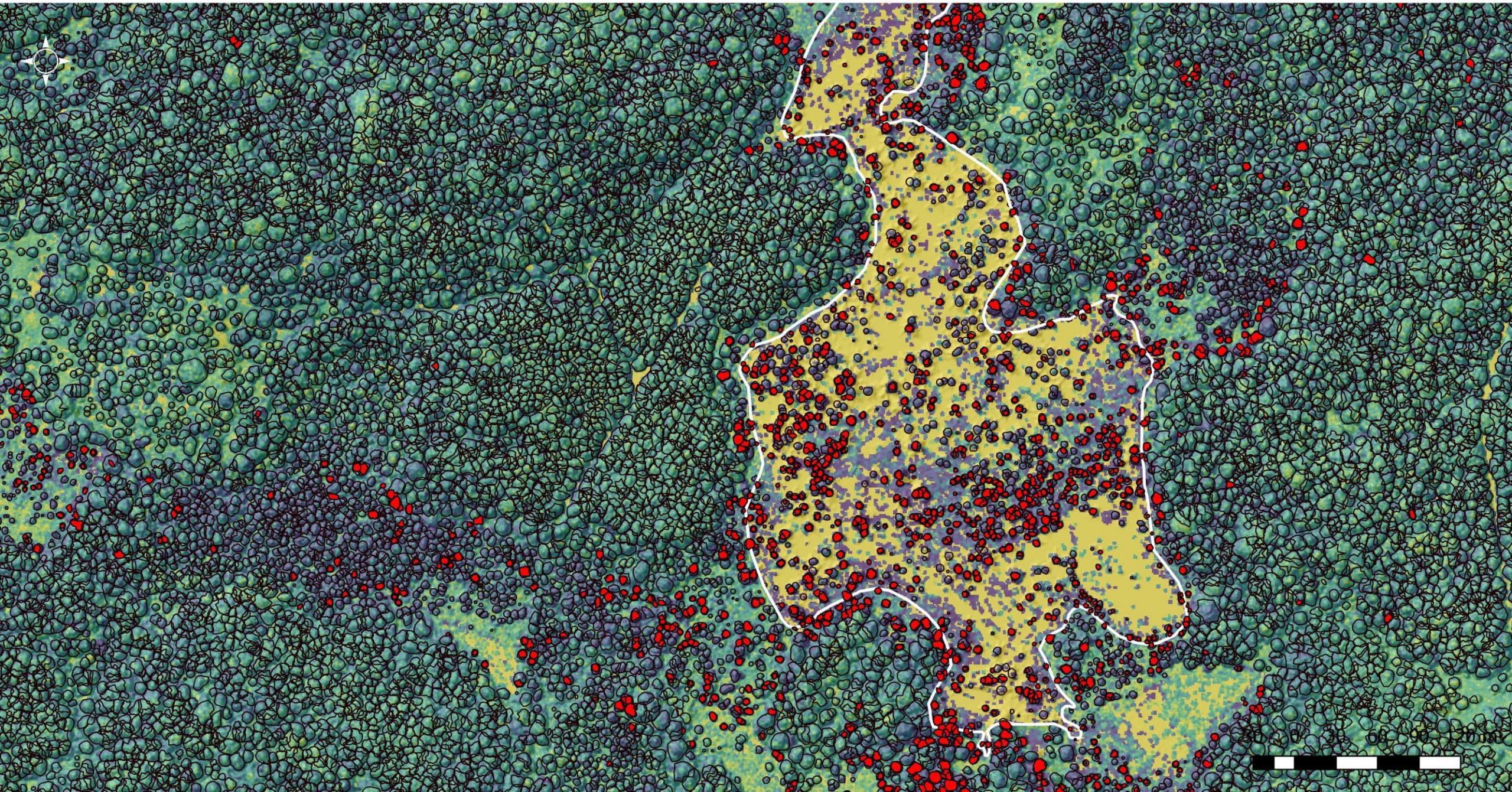

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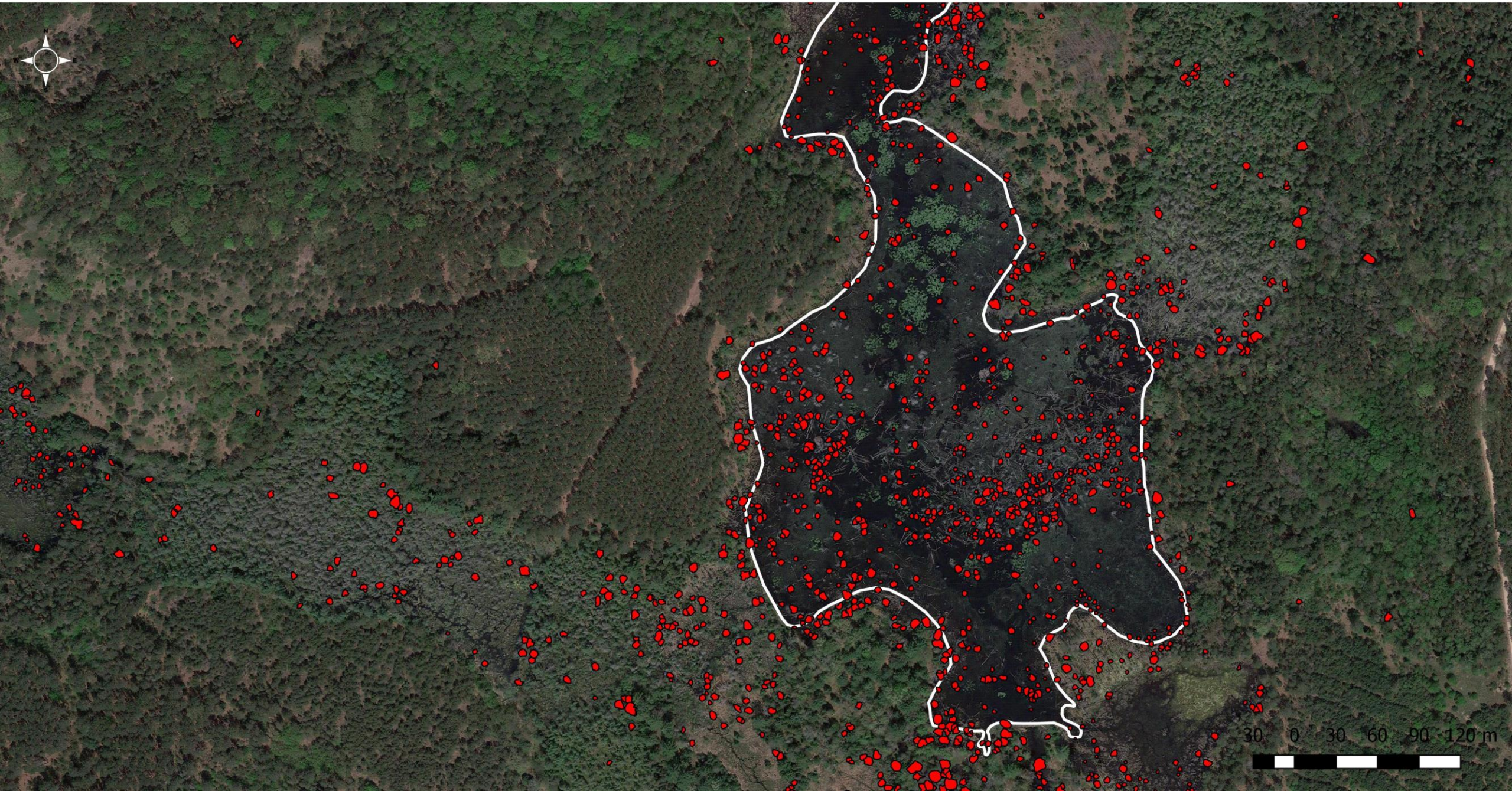
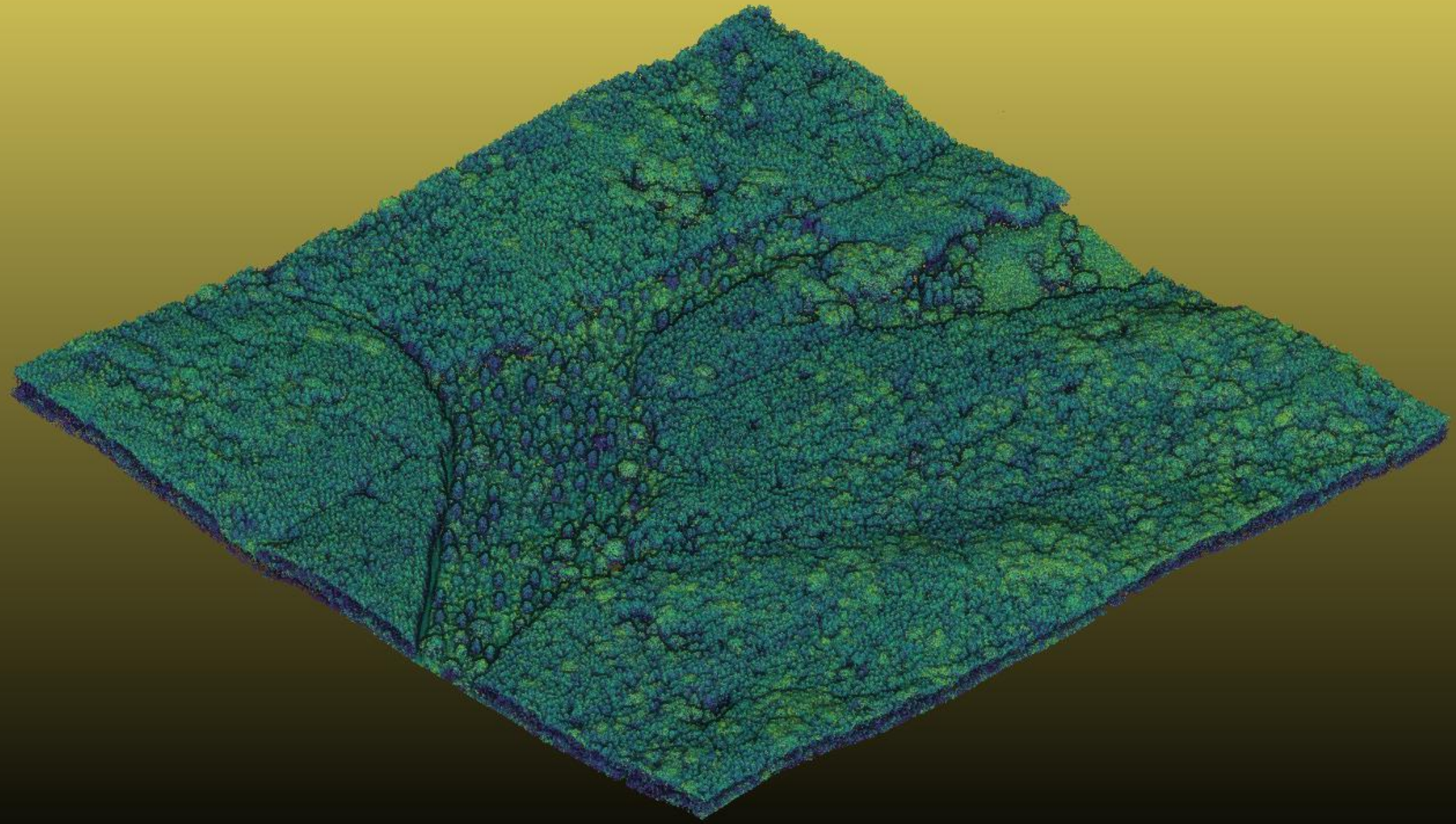
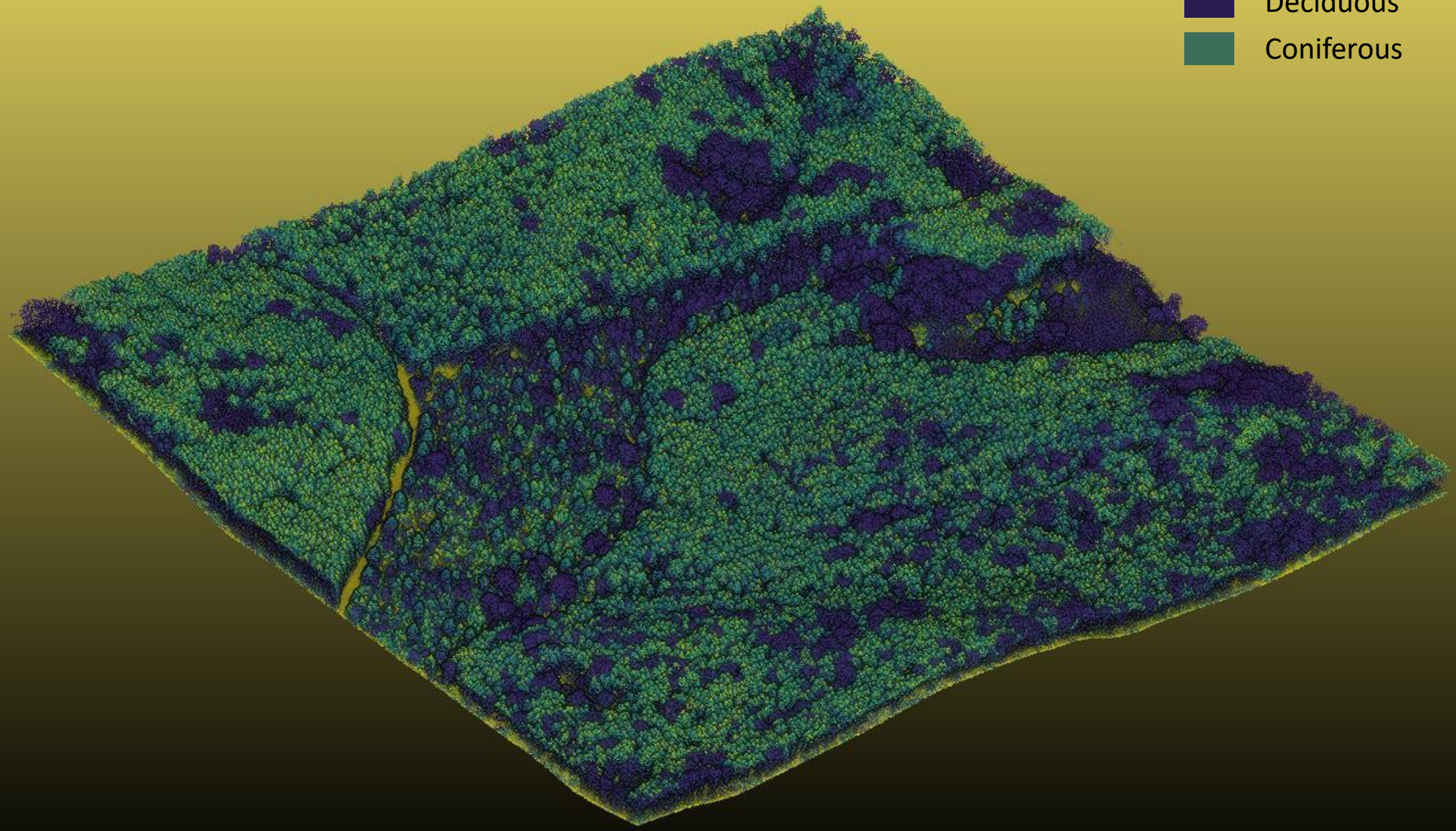


Mapping Conifer vs. Deciduous Using LiDAR Intensity Data (**Leaf-on / Summer**)



Summer Data Collection → Leaves on the trees → Better canopy model→ Detecting standing dead trees possible

Mapping Conifer vs. Deciduous Using LiDAR Intensity Data (**Leaf-off / Winter**)



Winter Data Collection → Leaves NOT on the deciduous trees → Better for detecting deciduous vs. coniferous

HABITAT MAPPING FOR THE AMERICAN MARTEN

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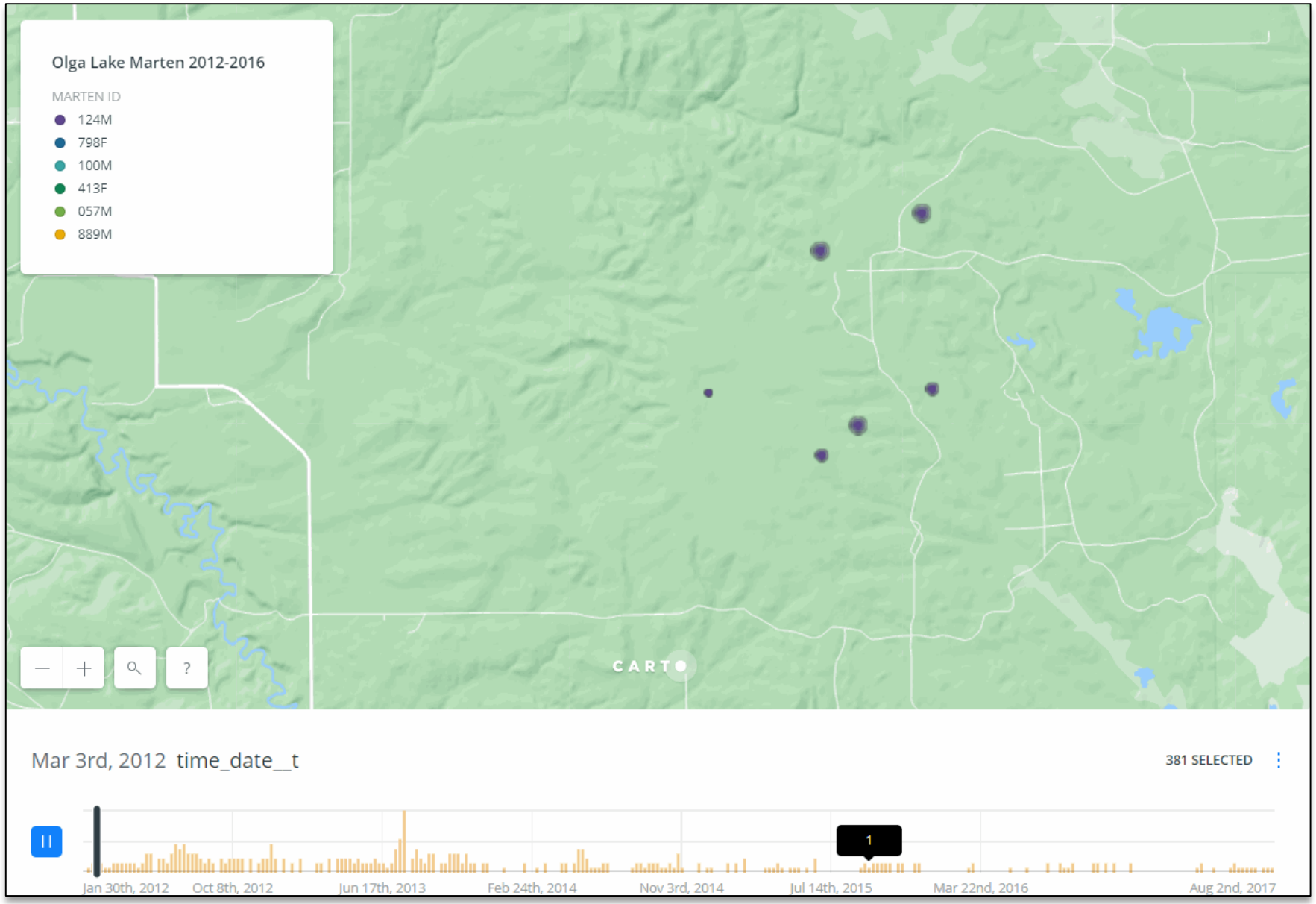
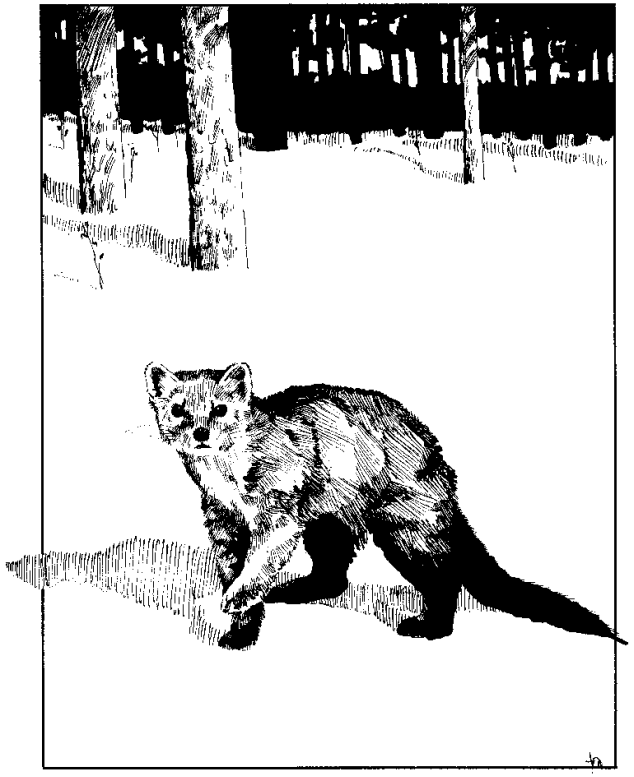
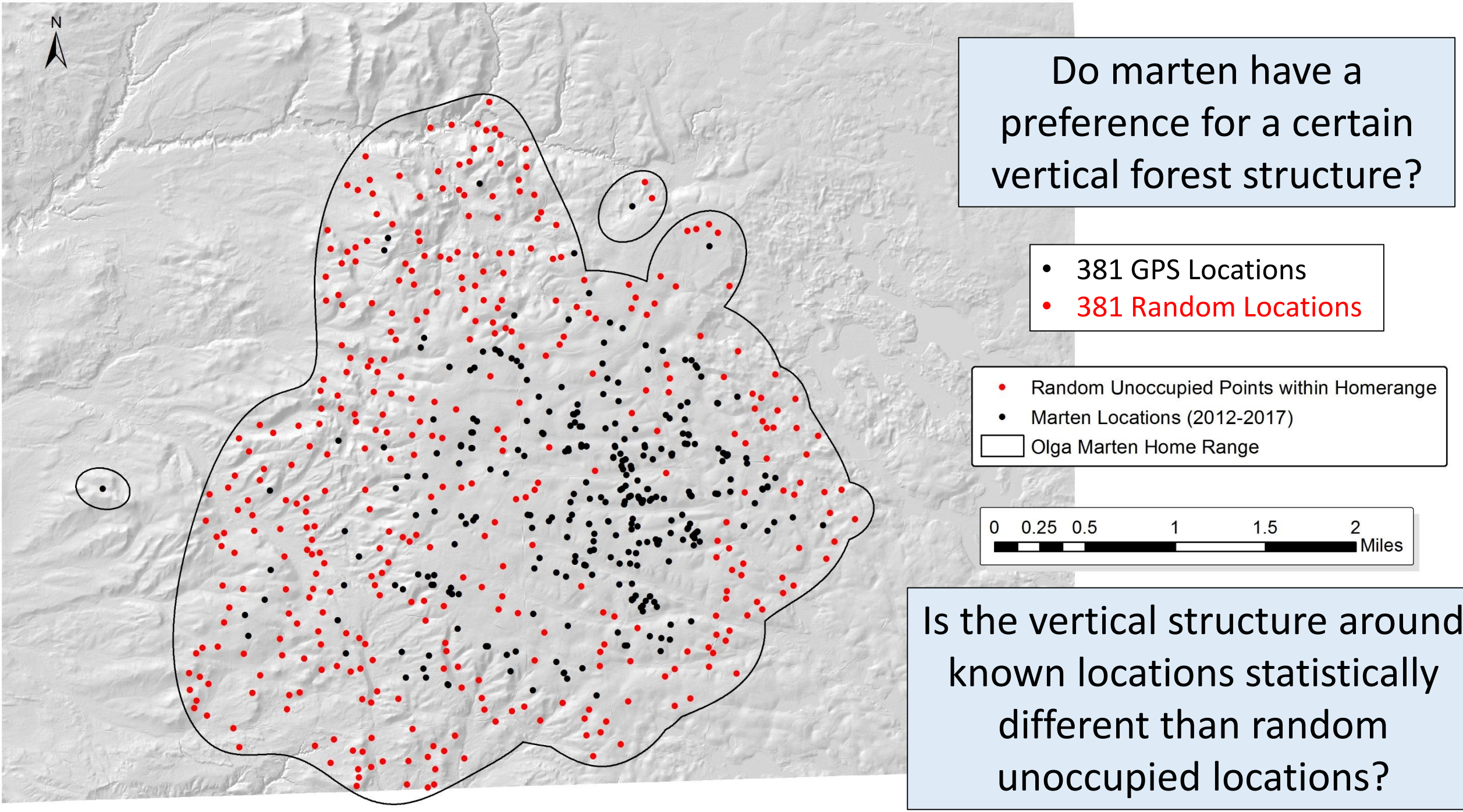






Do marten have a preference for a certain vertical forest structure?

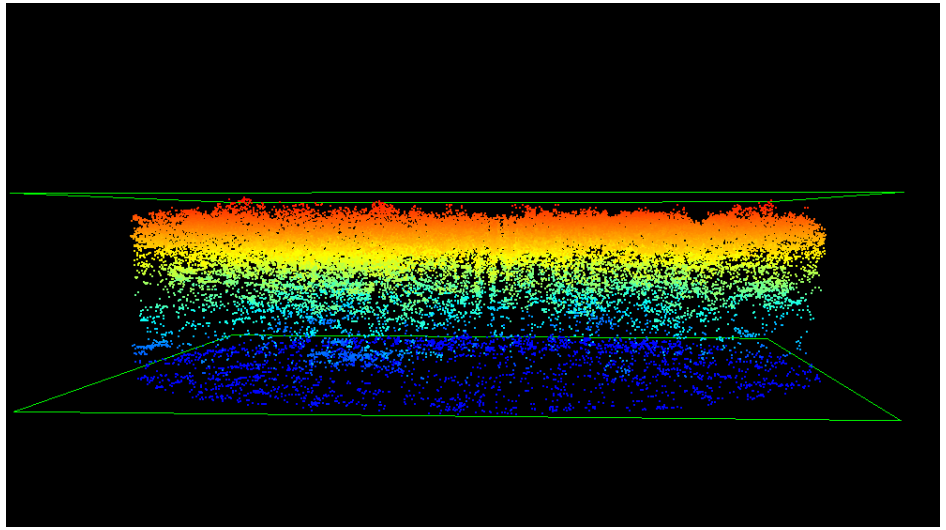
- 381 GPS Locations
- 381 Random Locations

Is the vertical structure around known locations statistically different than random unoccupied locations?

USING FUSION LIDAR SOFTWARE…

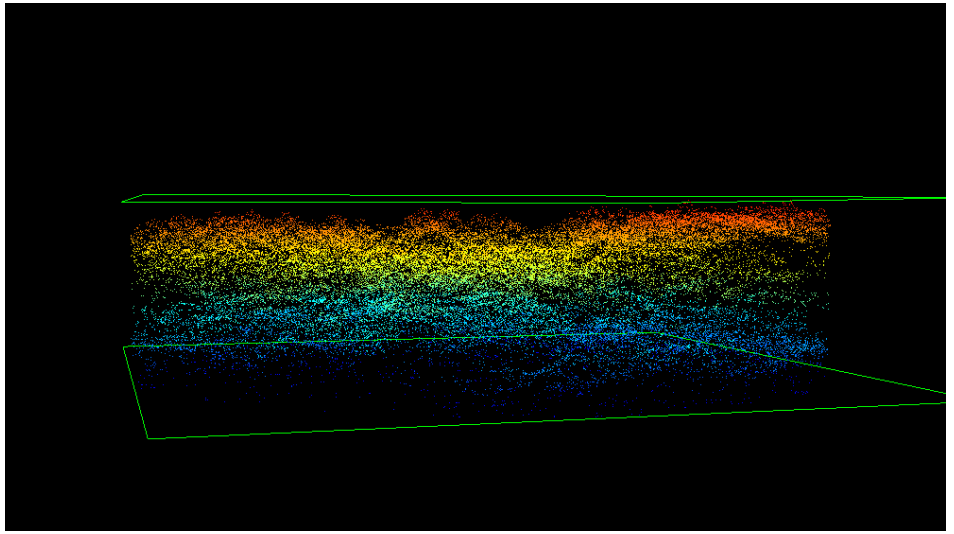
Characterize point cloud within 30-meter buffers around

known marten GPS locations



Characterize point cloud within 30-meter buffers around

random unoccupied locations



STEPS…

1. Normalize the points in each cloud to represent height above ground
2. “Slice” each point cloud into 2-meter height intervals
3. Run “Cloud Metrics” tool to determine the percent of LiDAR returns in each height strata
4. Pool each strata from each plot into a population of samples
5. Compare populations (known vs. random) to determine if they are statistically different.

Chosen Elevation Metric – **LiDAR Return Proportion** (at a given height strata)…

Known Marten Locations vs. Random Unoccupied Locations- are they statistically different? Yes. And this is true for all strata, except for…

Results of Student's T-Test to Evaluate Significant Differences between Random and Known Marten Location Elevation and Intensity Strata metrics

Bold P-values indicate that particular strata is not significantly different from random chance

Elev Strata (meters)	2-tailed, equal variance P-value	2-tailed, unequal variance P-value
Elev strata (below 0.50) return proportion	5.26E-03	5.28E-03
Elev strata (0.50 to 1.00) return proportion	1.25E-08	1.55E-08
Elev strata (1.00 to 2.00) return proportion	3.14E-16	4.98E-16
Elev strata (2.00 to 4.00) return proportion	1.85E-20	5.29E-20
Elev strata (4.00 to 6.00) return proportion	4.86E-20	1.02E-19
Elev strata (6.00 to 8.00) return proportion	1.89E-11	2.29E-11
Elev strata (8.00 to 10.00) return proportion	1.18E-03	1.19E-03
Elev strata (10.00 to 12.00) return proportion	**3.27E-01**	**3.27E-01**
Elev strata (12.00 to 14.00) return proportion	5.90E-07	6.00E-07
Elev strata (14.00 to 16.00) return proportion	7.04E-21	7.04E-21
Elev strata (16.00 to 18.00) return proportion	5.36E-36	5.48E-36
Elev strata (18.00 to 20.00) return proportion	4.26E-35	6.20E-35
Elev strata (20.00 to 22.00) return proportion	7.52E-04	7.52E-04
Elev strata (22.00 to 24.00) return proportion	8.60E-10	8.60E-10
Elev strata (24.00 to 26.00) return proportion	6.72E-24	4.48E-23
Elev strata (26.00 to 28.00) return proportion	1.03E-14	2.83E-14
Elev strata (28.00 to 30.00) return proportion	2.36E-07	3.00E-07

Vertical Structure of Occupied Forests within Marten Home Range as Derived from Pooled LiDAR Cloud Metrics of 30-meter Circular Buffers Around Known Marten Locations (n=381)

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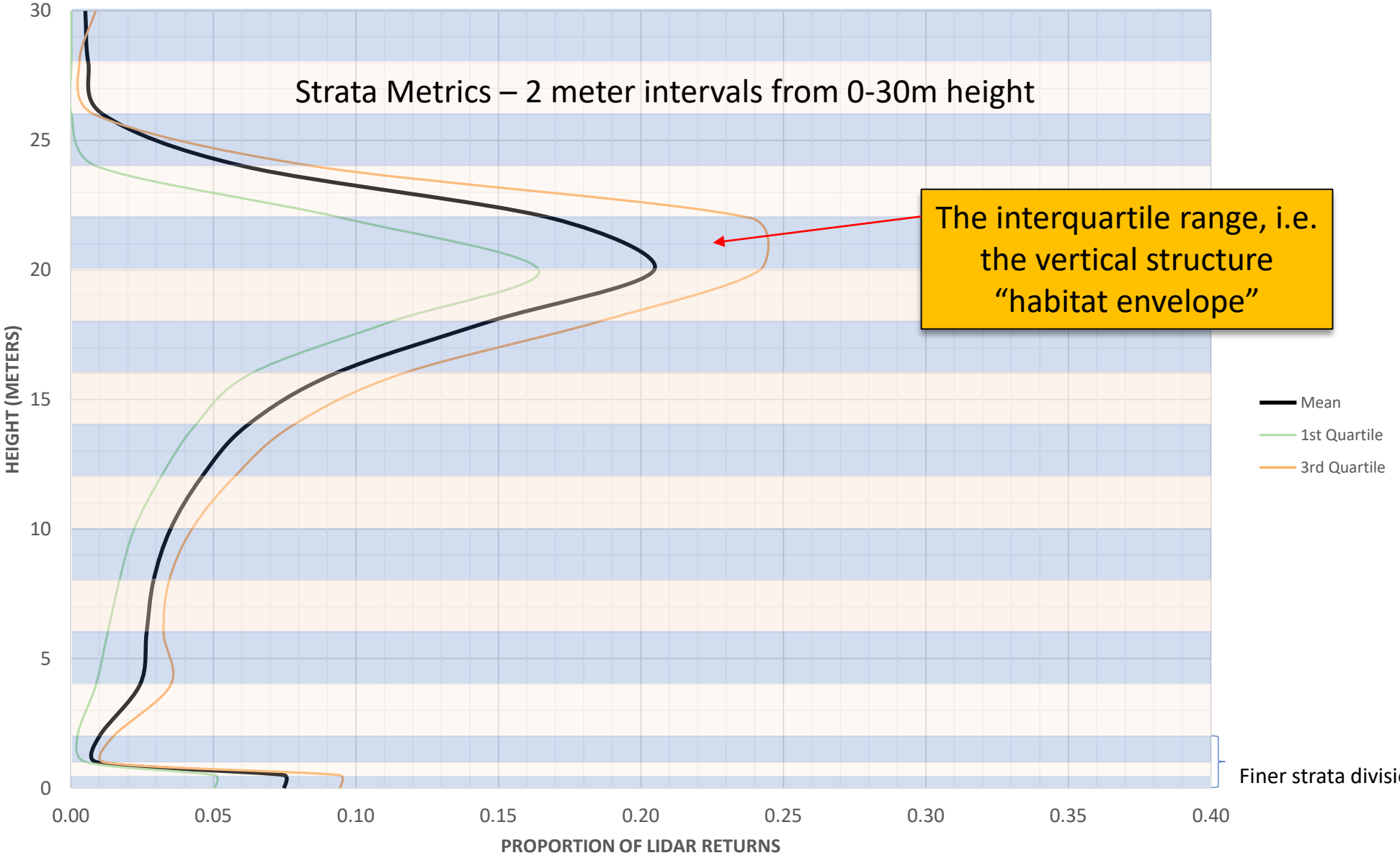

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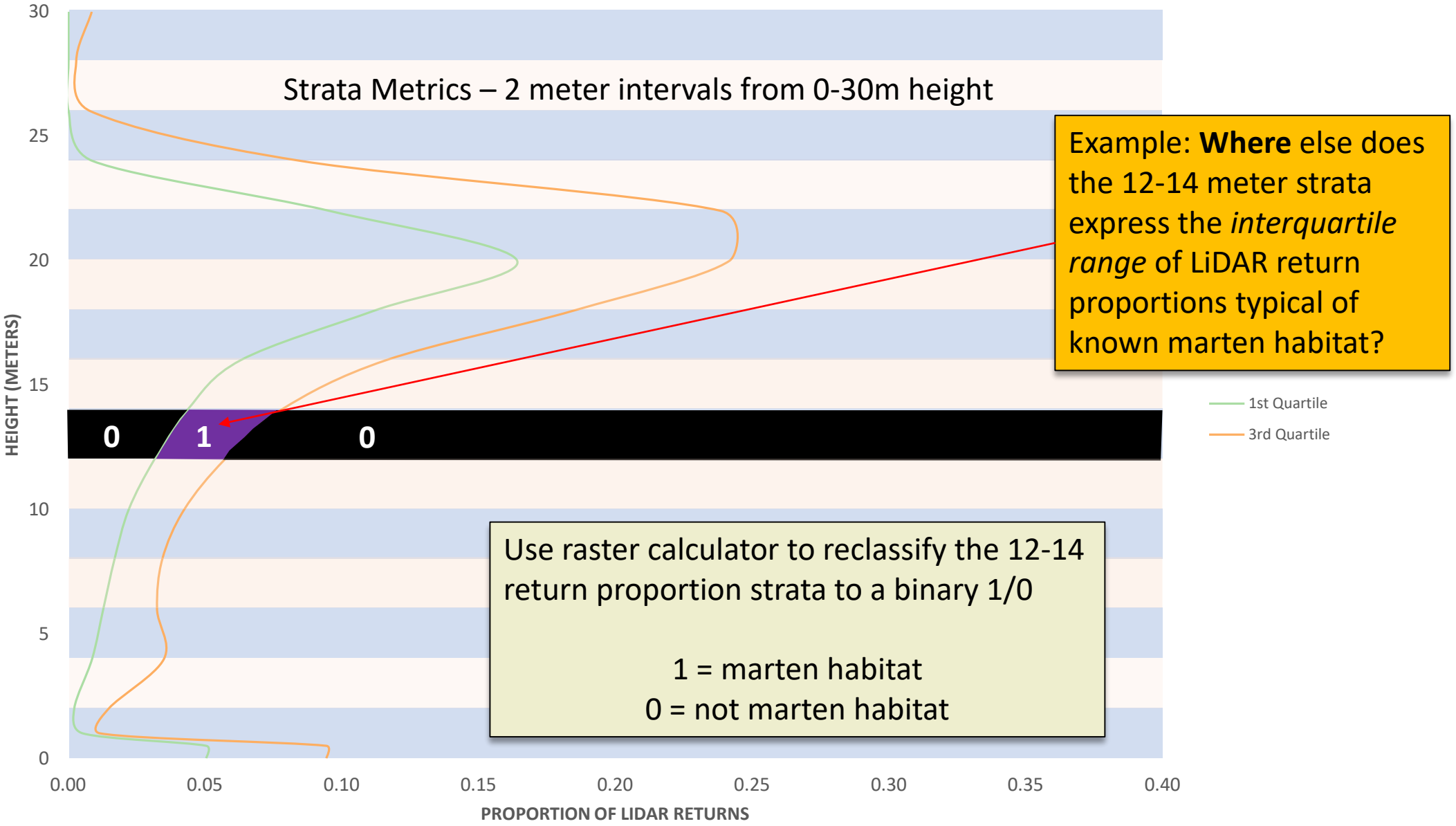

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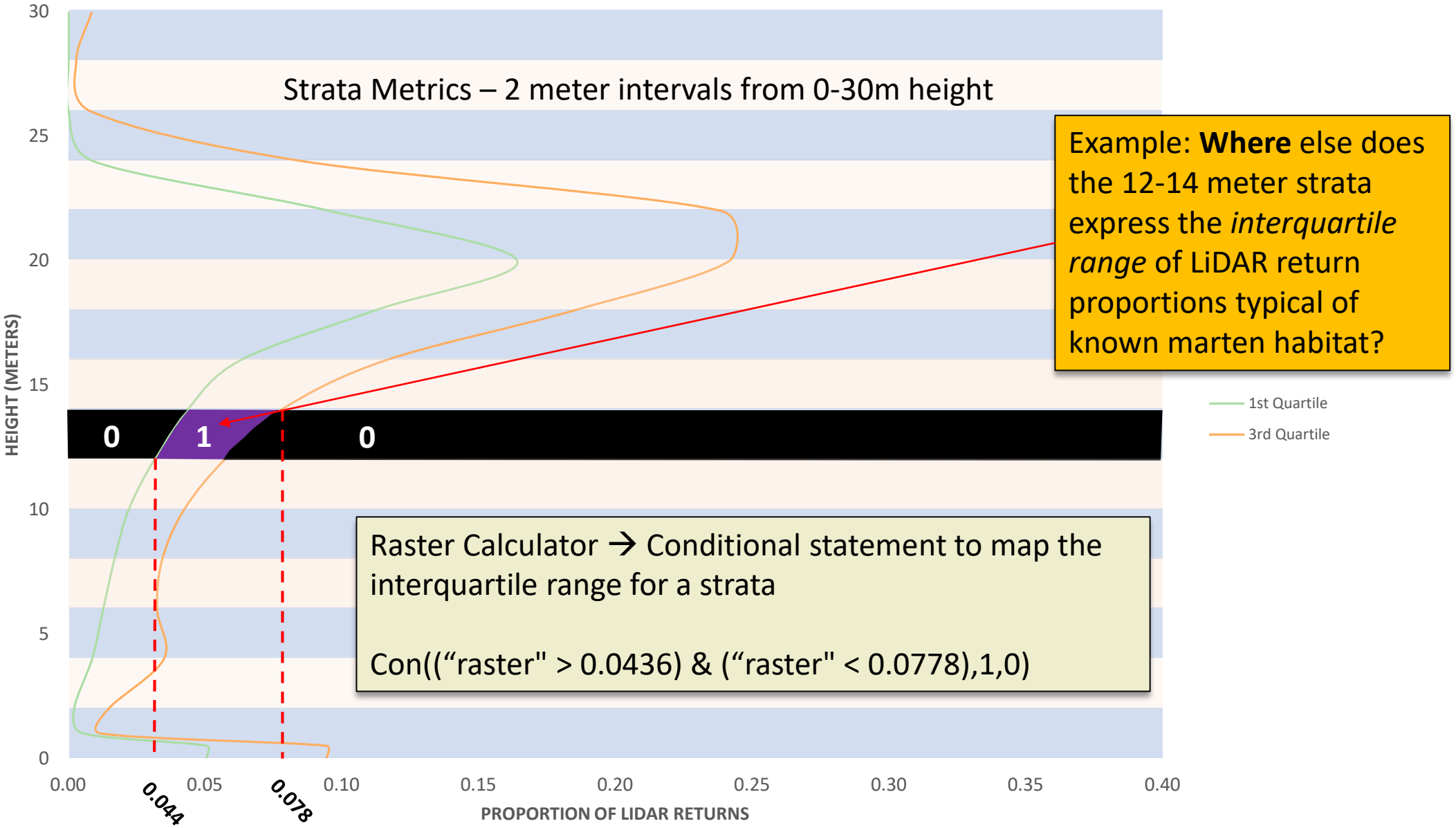

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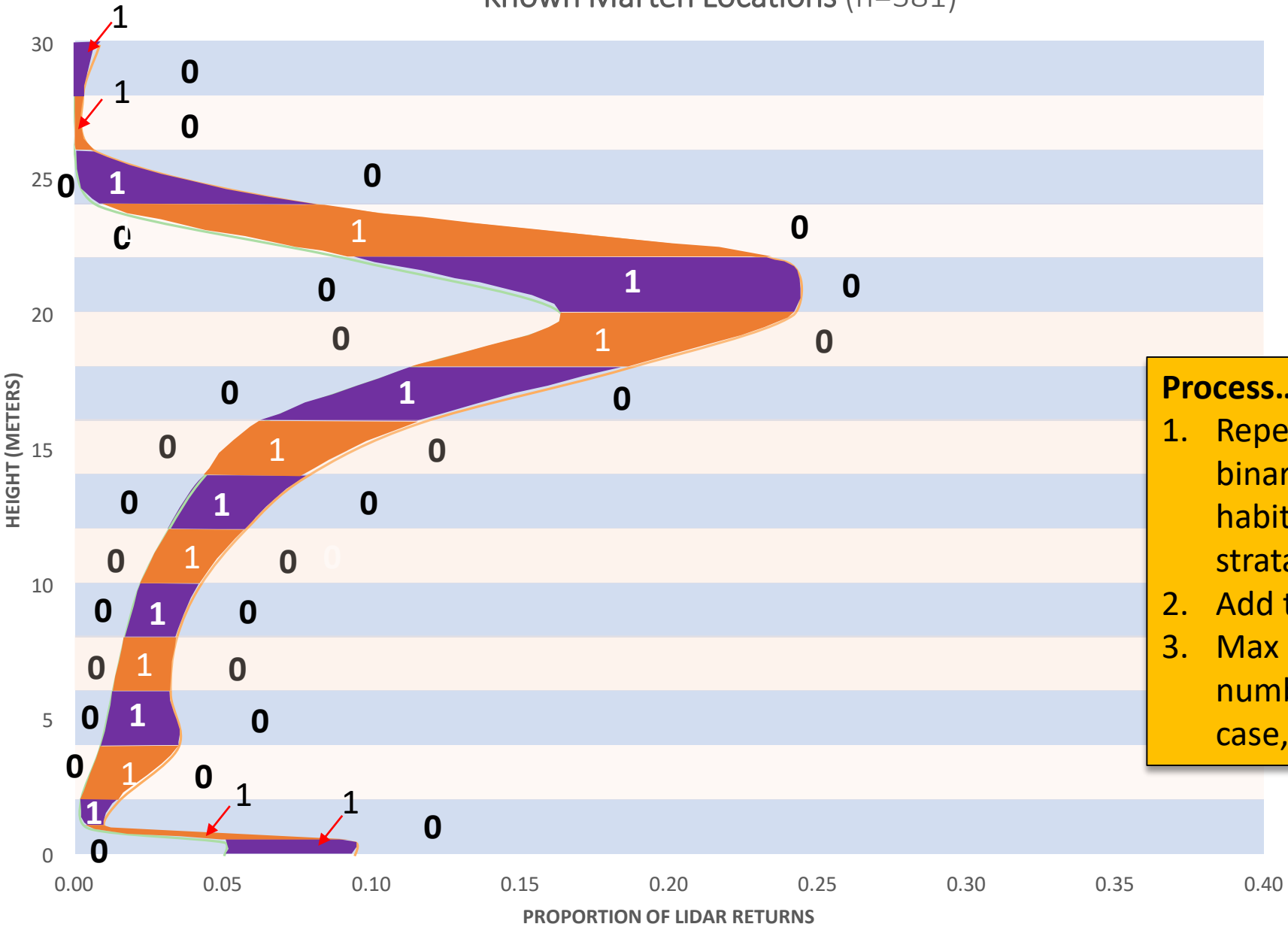
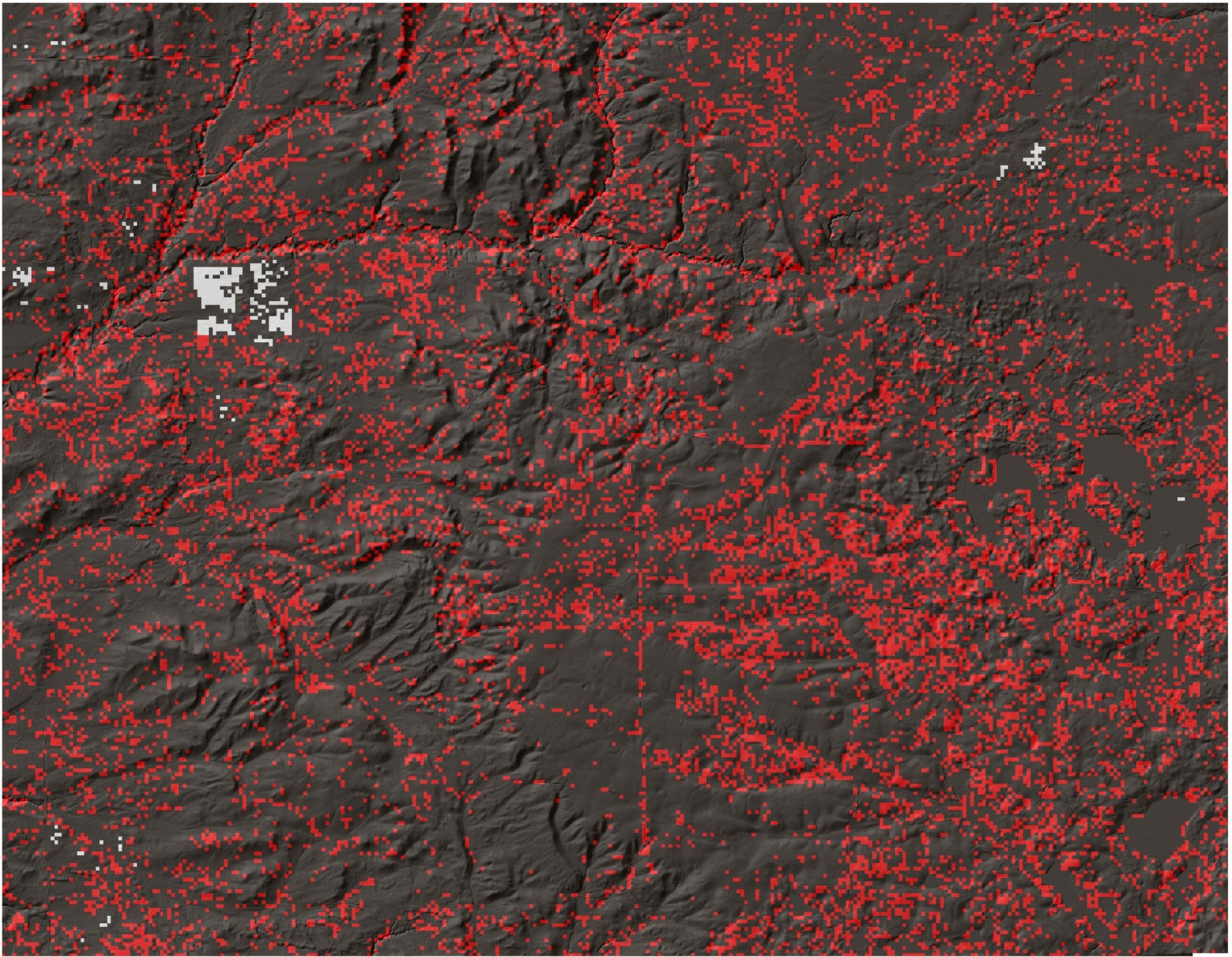


Process…

1. Repeat the generation of binary 1/0 (habitat/not habitat) rasters for each strata
2. Add them up!
3. Max possible index “score” = number of strata (in this case, 17)



Example: **Where** does the 12-14 meter strata express the *interquartile range* of LiDAR return proportions typical of known marten habitat?

LiDAR Return Proportion 12-14 meters strata

0 - not within IQ range

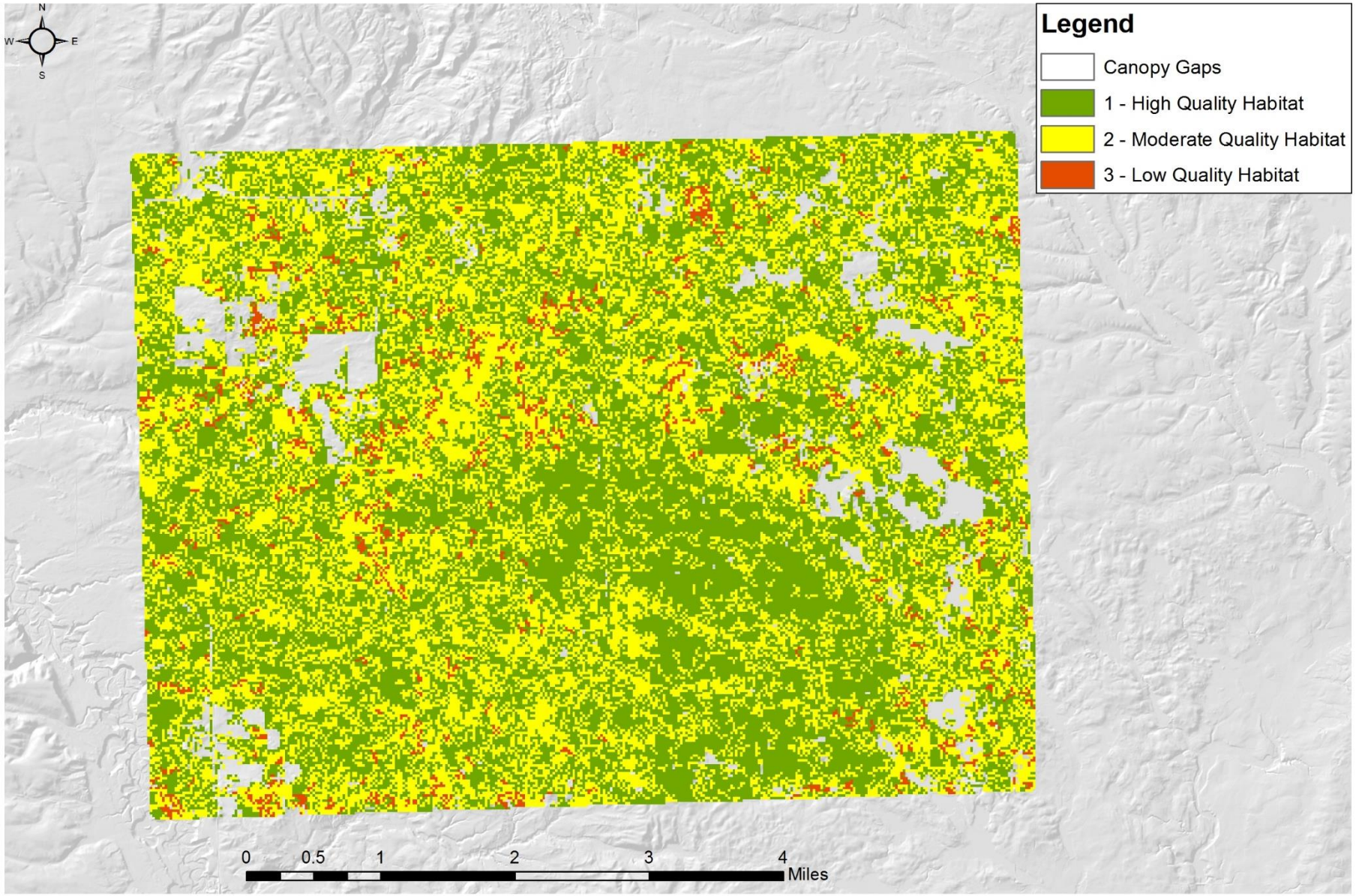
1 - within IQ range

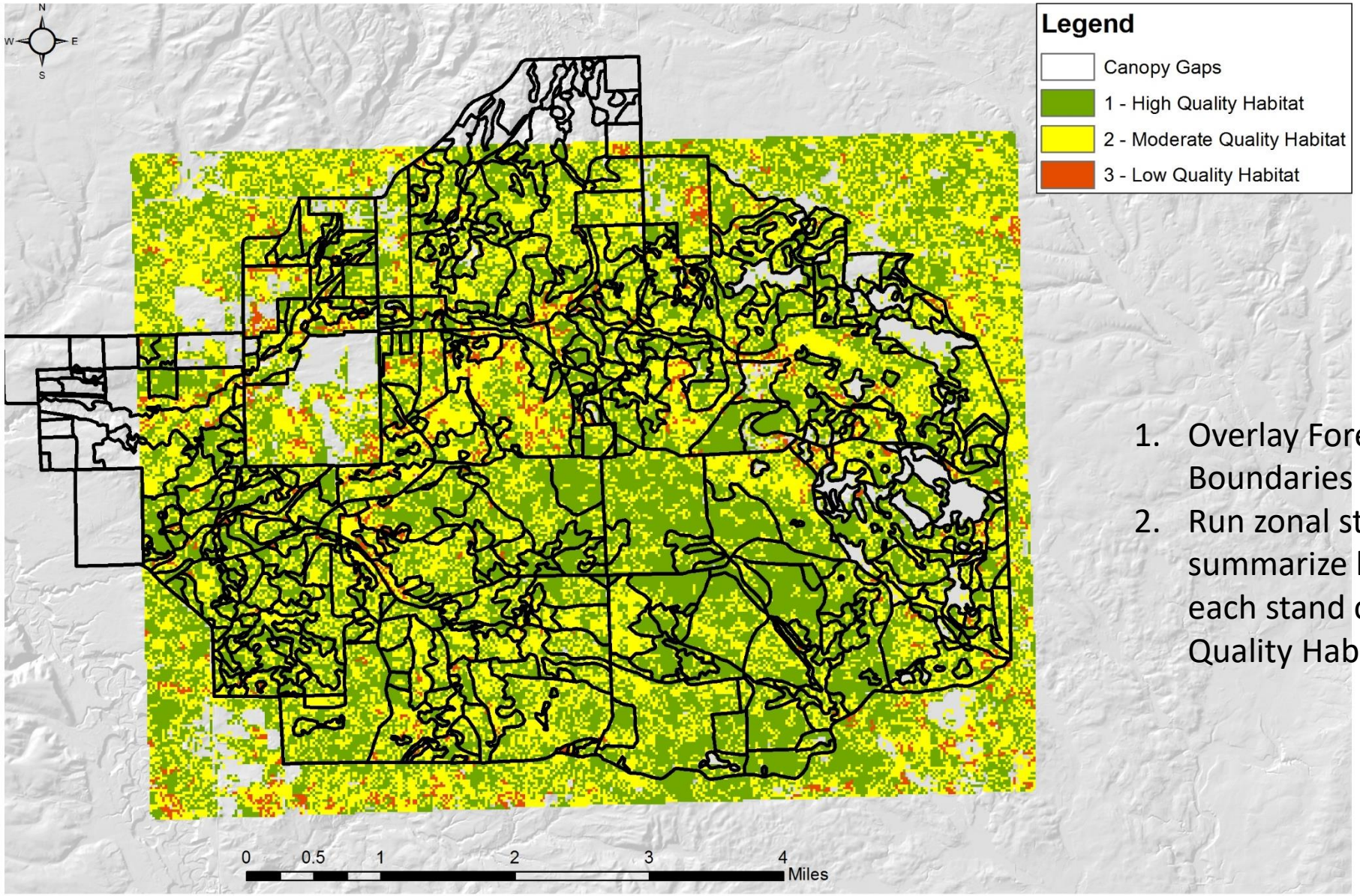
0 0.5 1 1.5 Miles

N

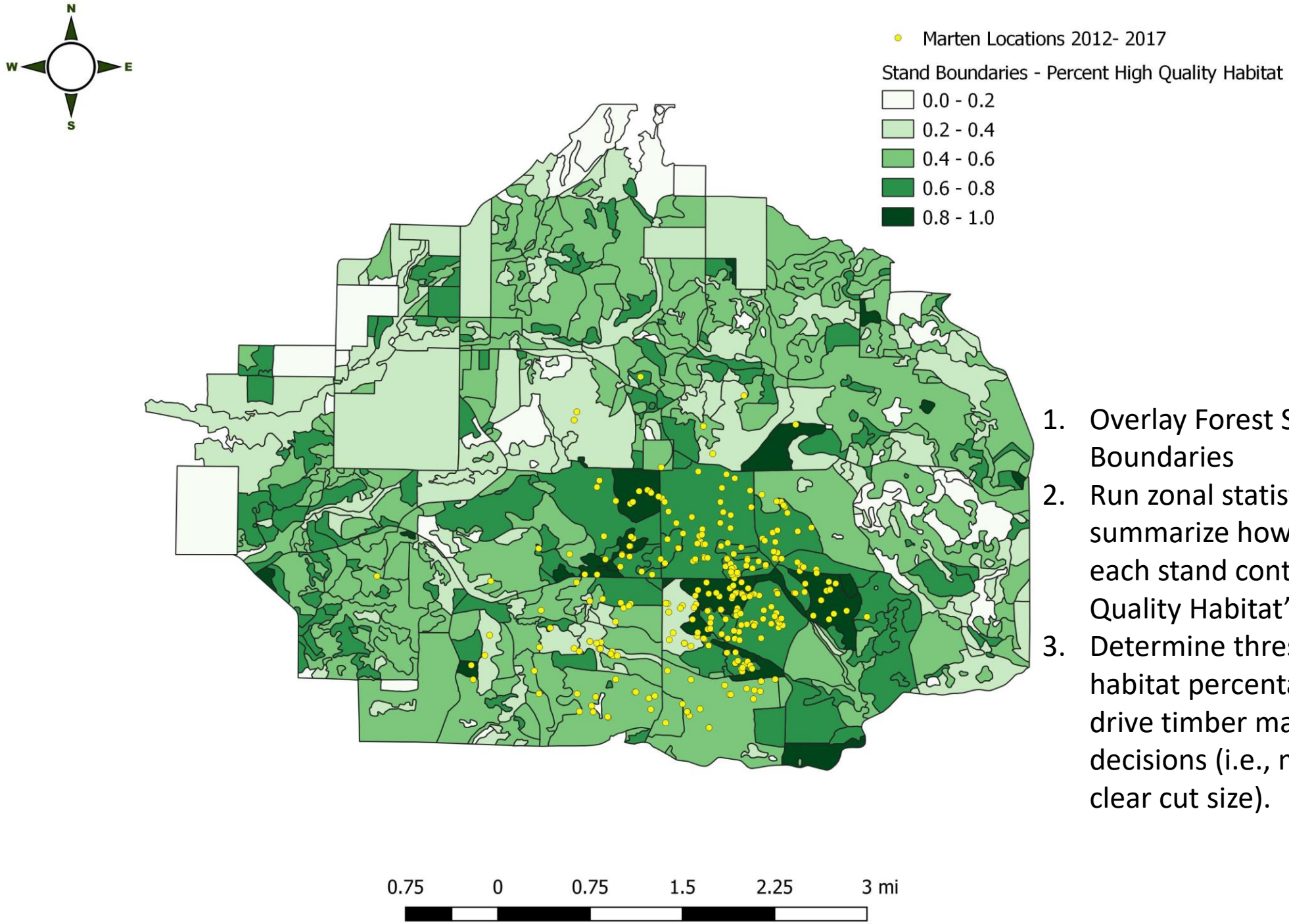
Raster Calculator →

Con((“raster" > 0.0436) & (“raster" < 0.0778),1,0)

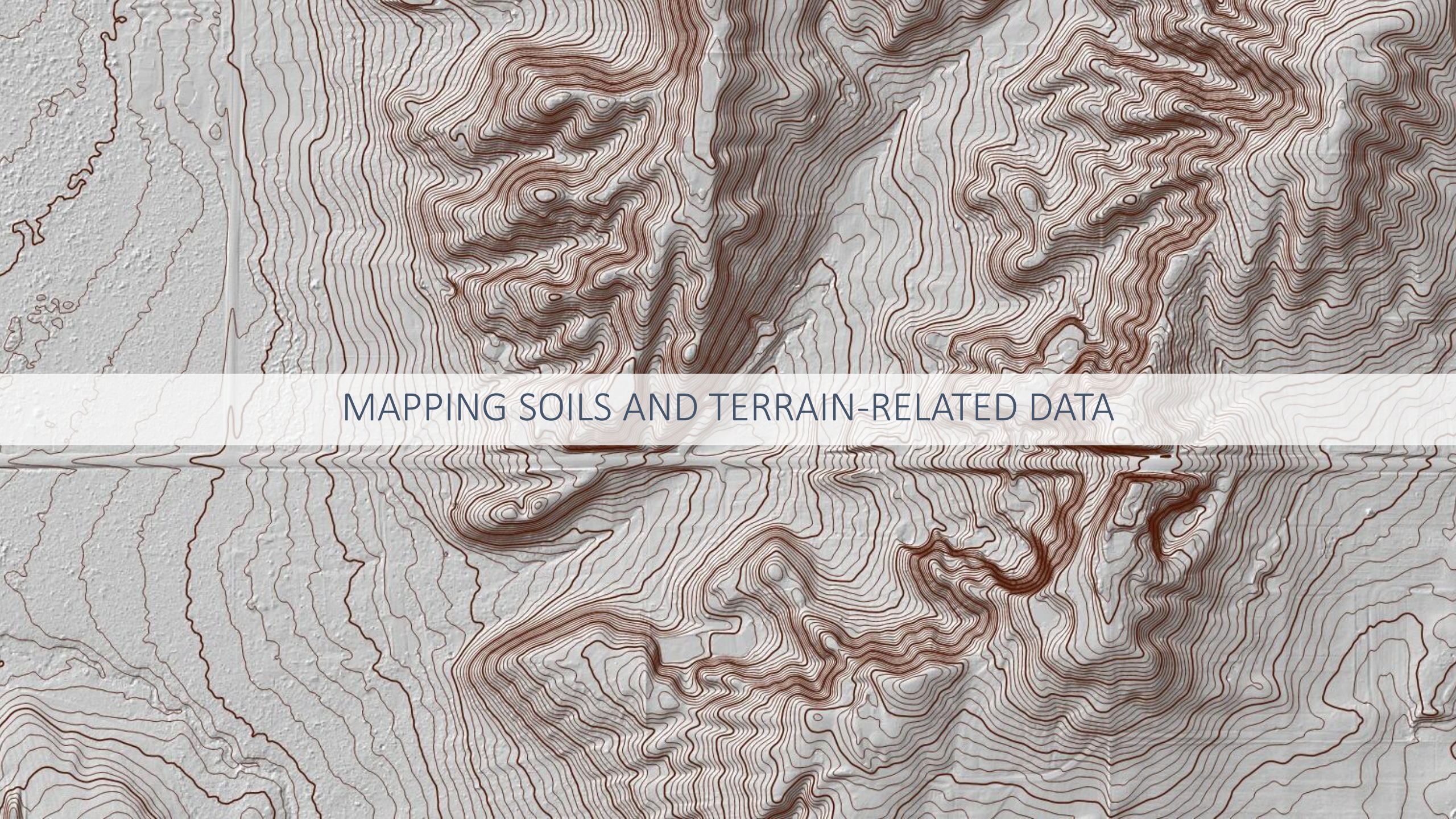

N
W
E
S
Legend
Canopy Gaps
1 - High Quality Habitat
2 - Moderate Quality Habitat
3 - Low Quality Habitat
0
0.5
1
2
3
4
Miles



1. Overlay Forest Stand Boundaries
2. Run zonal statistics to summarize how much of each stand contains “High Quality Habitat”



1. Overlay Forest Stand Boundaries
2. Run zonal statistics to summarize how much of each stand contains “High Quality Habitat”
3. Determine thresholds for habitat percentage that drive timber management decisions (i.e., maximum clear cut size).



MAPPING SOILS AND TERRAIN-RELATED DATA

MAPPING SOILS AND TERRAIN-RELATED DATA

TOPICS TO EXPLORE…

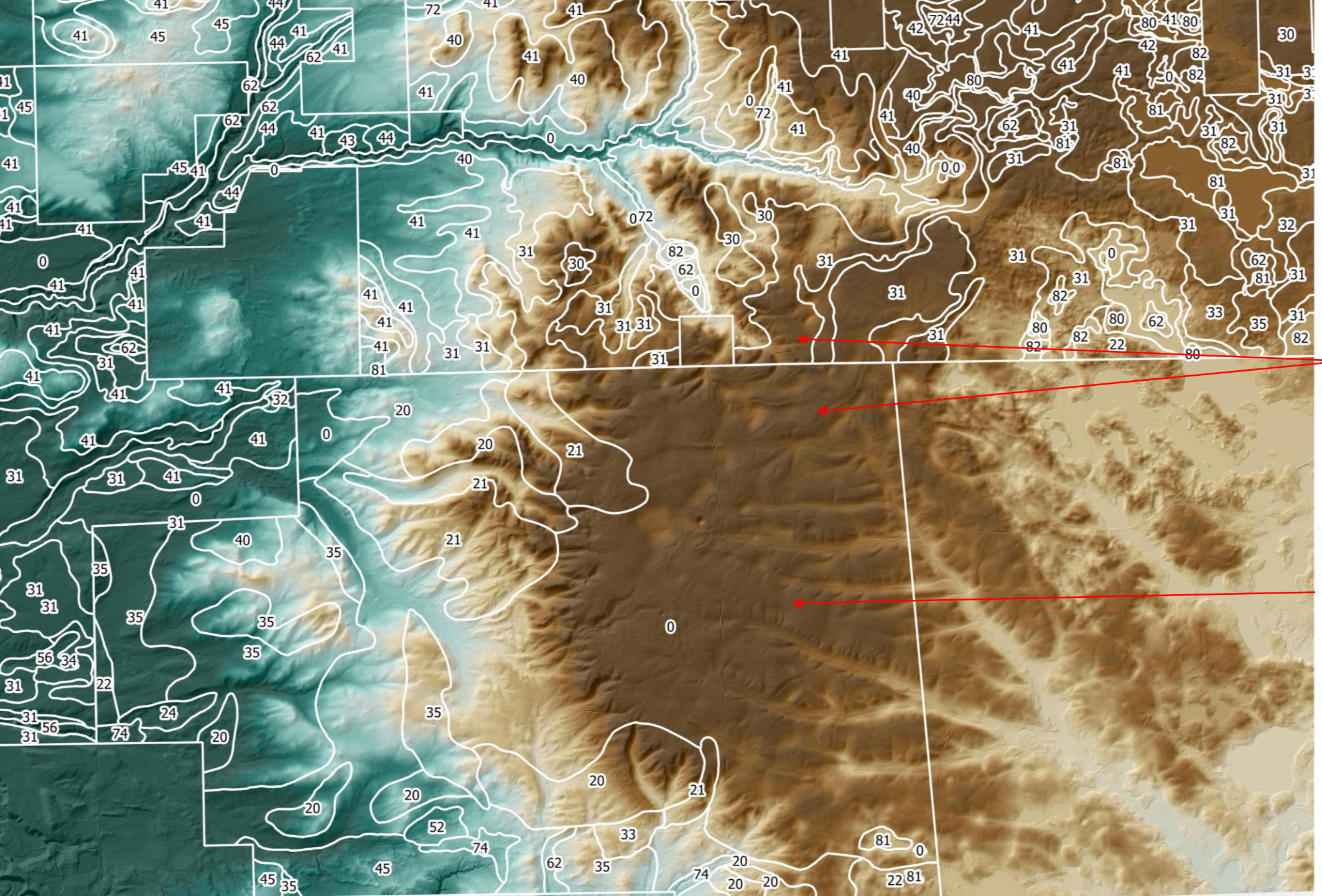
1. Having access to LiDAR, especially in glaciated (or otherwise “subtle” terrain) improves…
    - Geomorphic interpretation
    - Existing map unit boundaries

MAPPING SOILS AND TERRAIN-RELATED DATA

TOPICS TO EXPLORE…

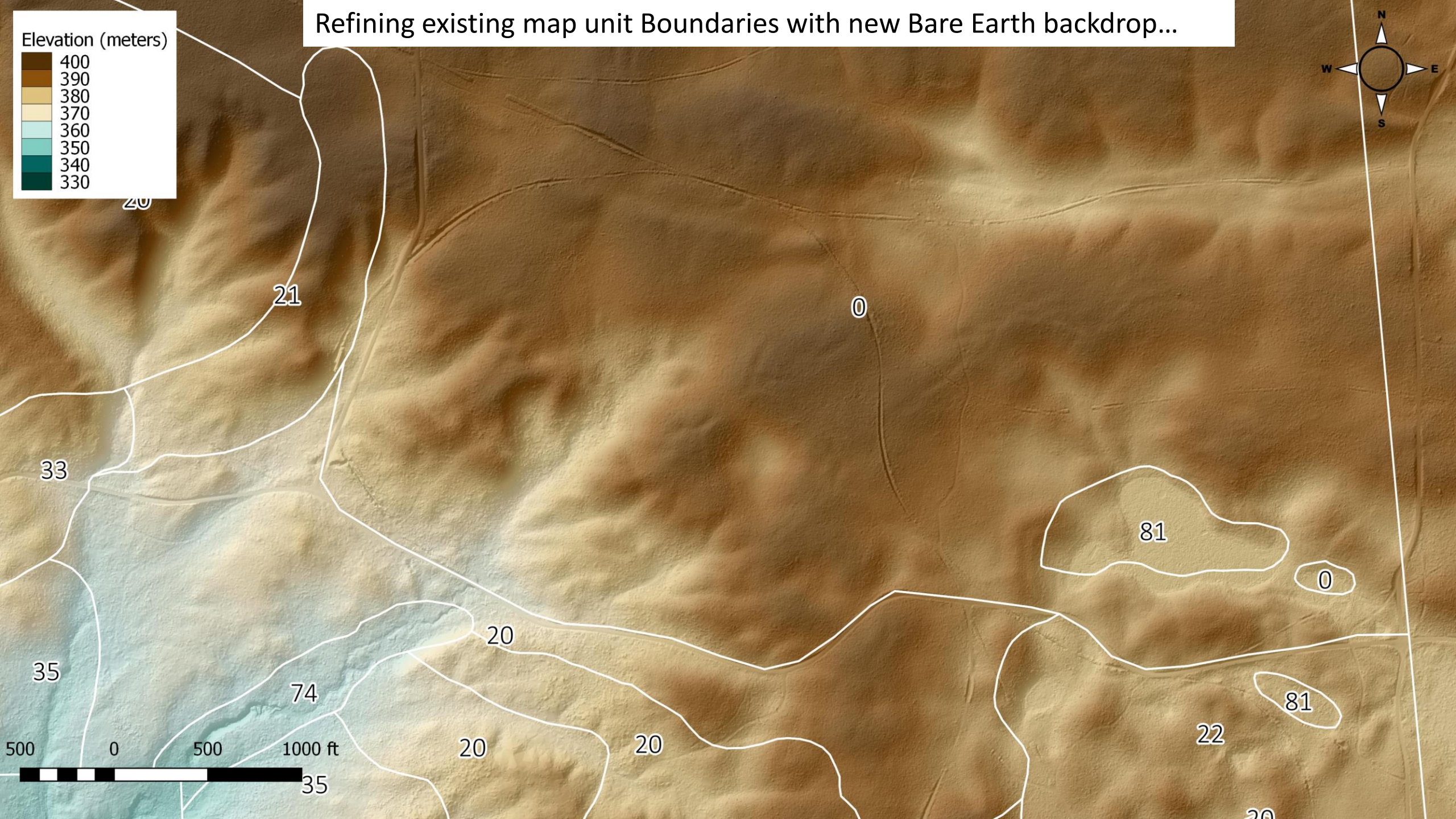
1. Having access to LiDAR, especially in glaciated (or otherwise “subtle” terrain) improves…
    - Geomorphic Interpretation
    - Existing map unit boundaries

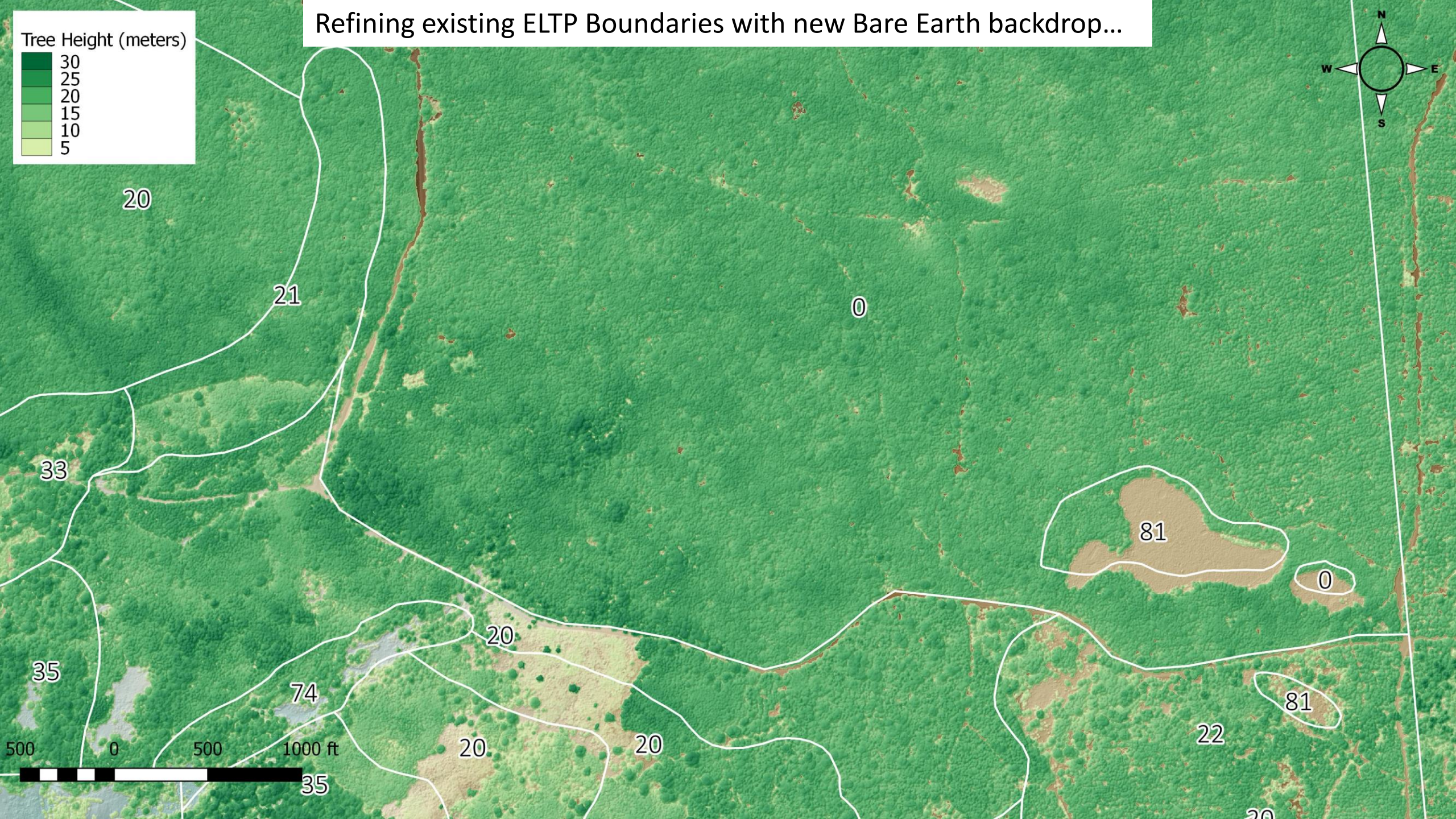
2. Zonal statistics is a fundamental tool for map unit delineation…
    - Is higher resolution raster data better? Or a burden?
    - What steps can be taken to work with data more efficiently?



Existing Soil Map Unit Boundaries

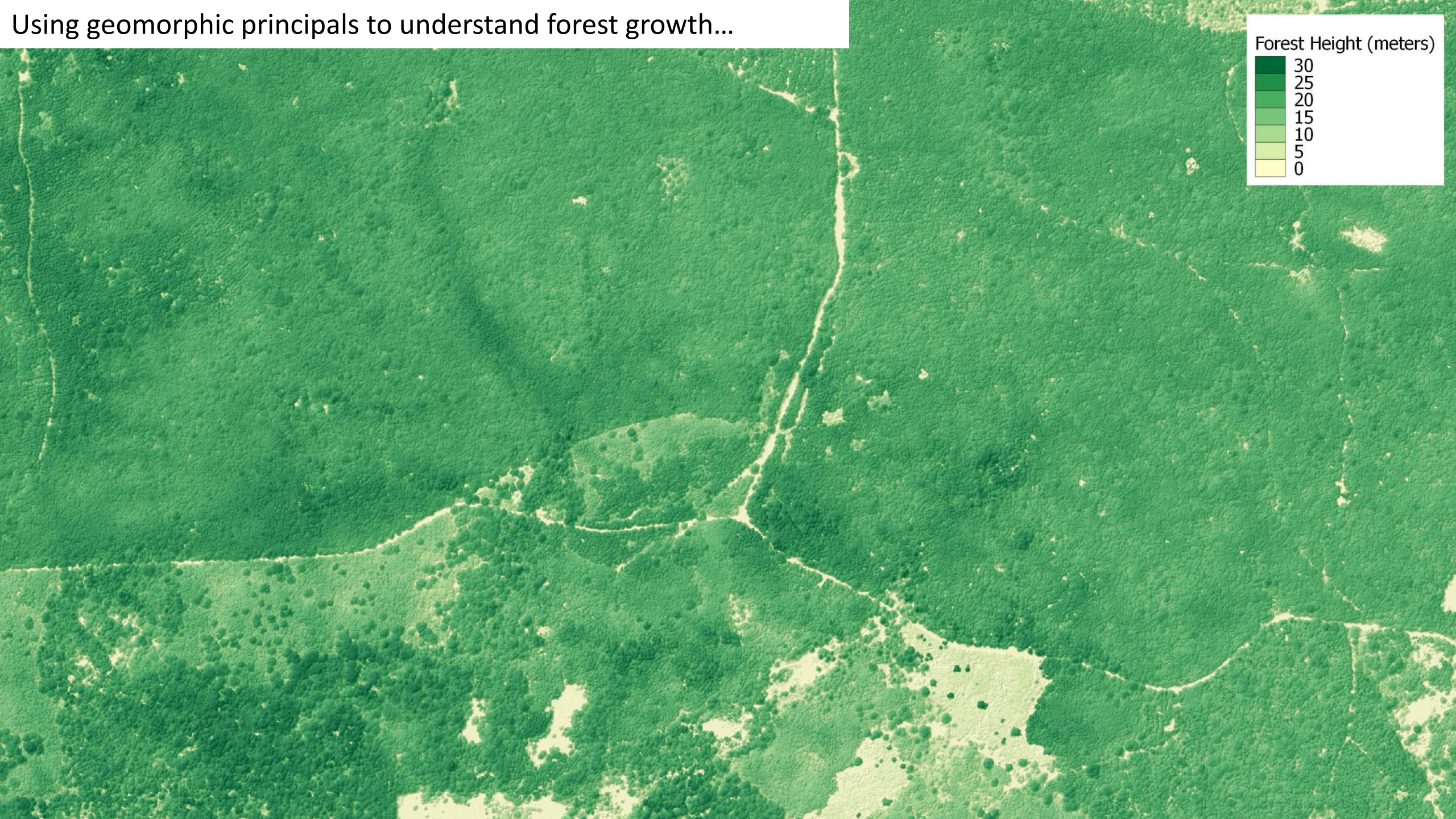
- Draft completed in the late 90s against 1:24K black and white aerial photo base
- Mismatched units across contract boundaries
- Unassigned map unit symbols
- Units not capturing sufficient detail


Refining existing map unit Boundaries with new Bare Earth backdrop…
Elevation (meters)
400
390
380
370
360
350
340
330
N
W
E
S
20
21
0
33
81
0
20
35
74
81
22
20
20
500
0
500
1000 ft
35

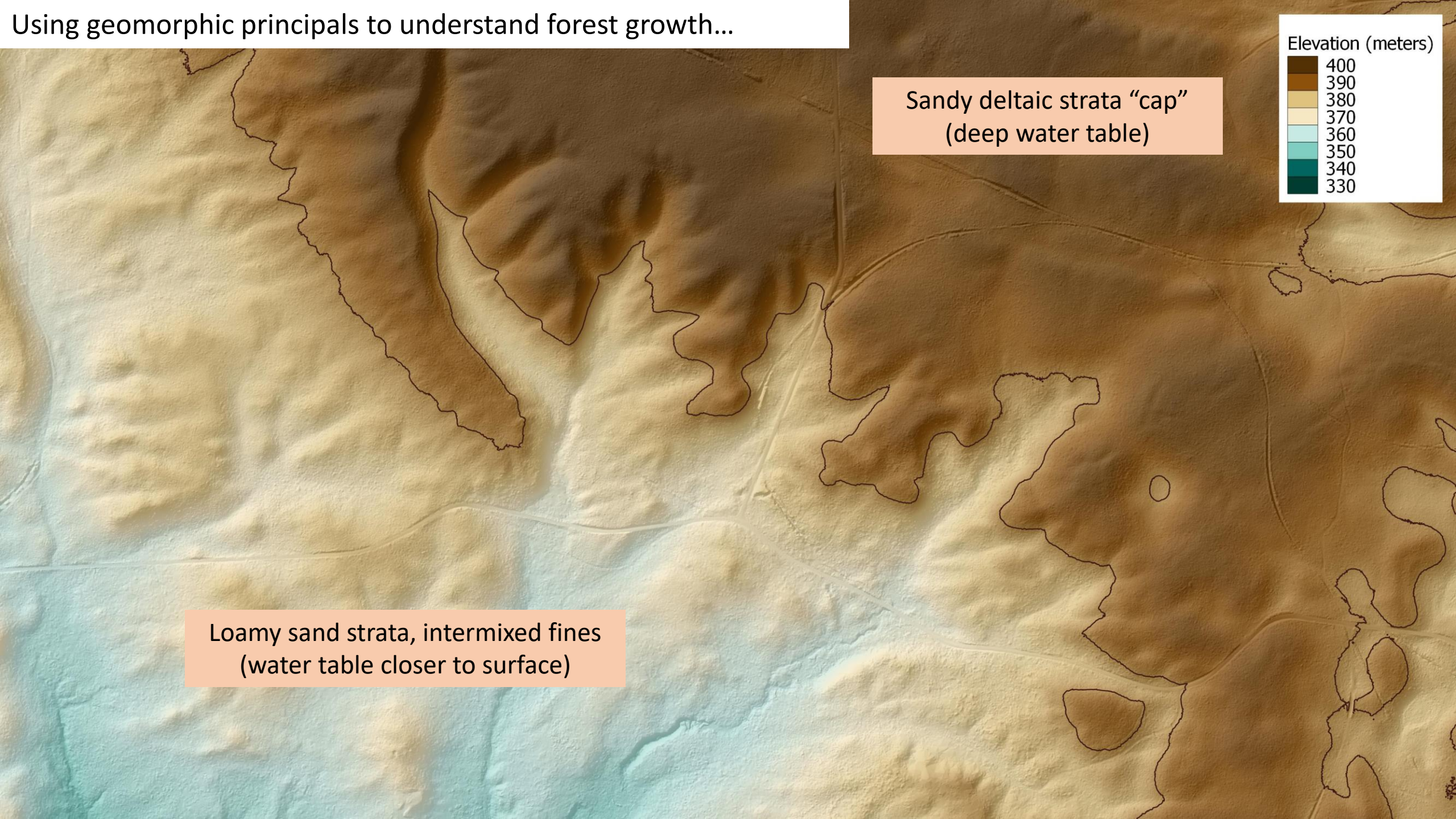

Refining existing ELTP Boundaries with new Bare Earth backdrop…
Tree Height (meters)
30
25
20
15
10
5
N
W
E
S
20
21
0
33
81
0
20
35
74
81
22
20
20
35
500
0
500
1000 ft

Using geomorphic principals to understand forest growth…

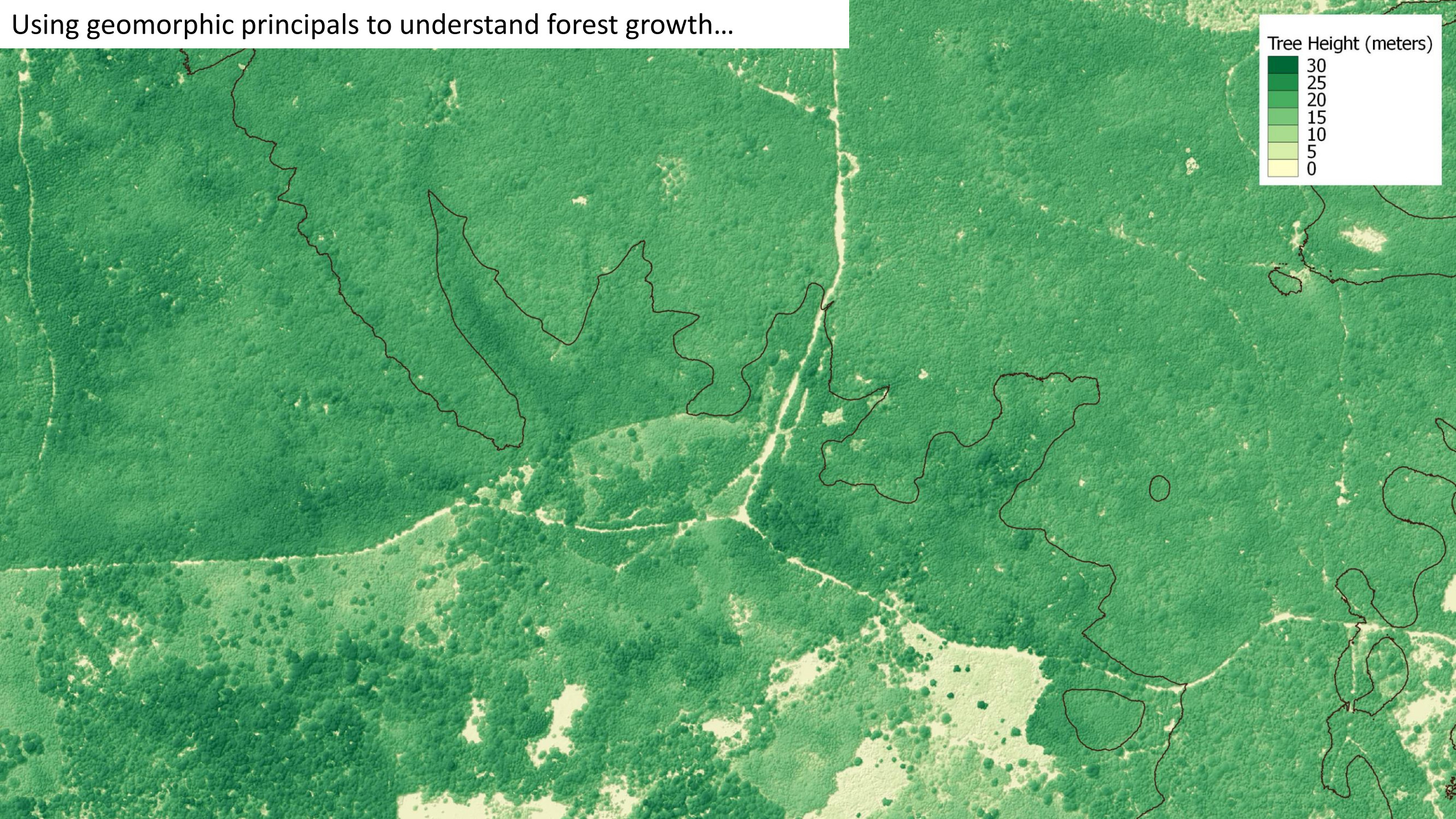
Using geomorphic principals to understand forest growth…



Using geomorphic principals to understand forest growth…



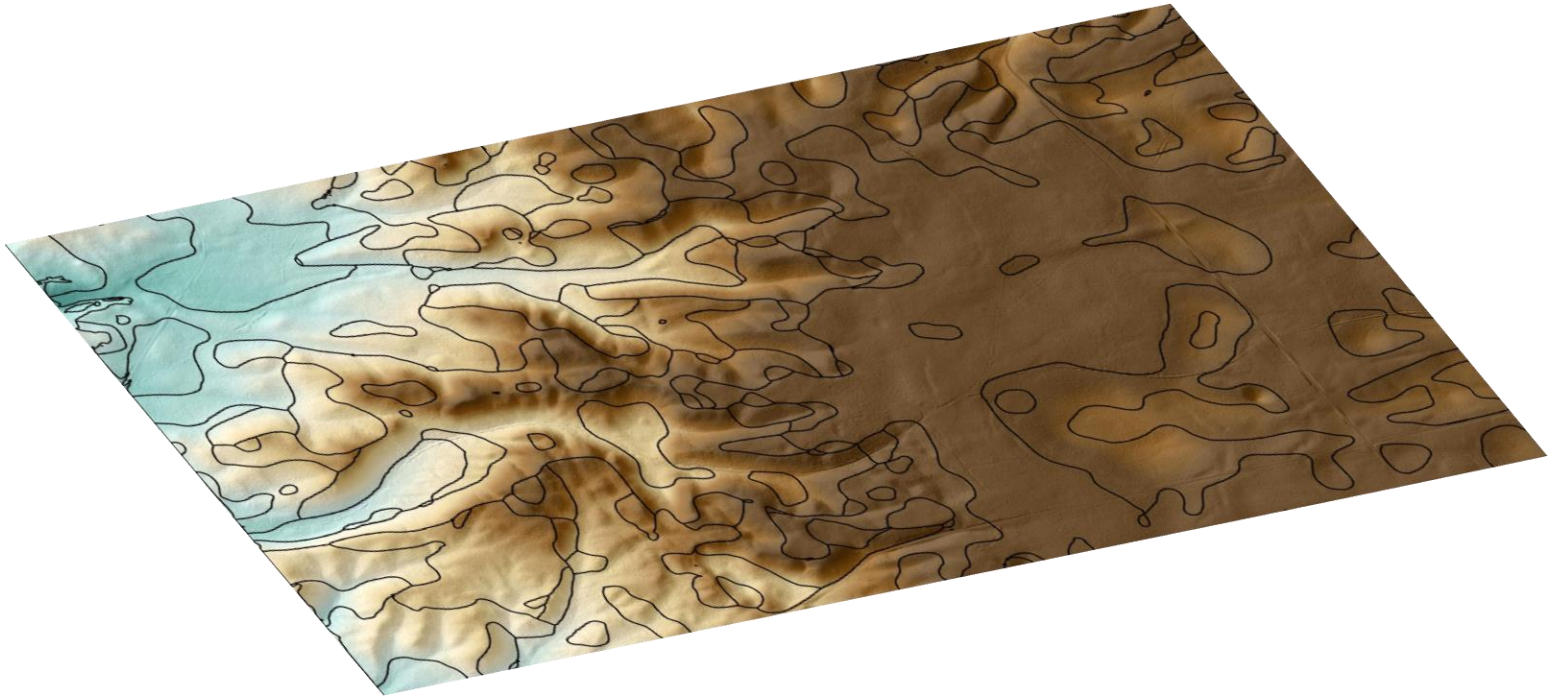
Using geomorphic principals to understand forest growth…



Soils Mapping and Zonal Statistics with LiDAR Data

Starting with basic terrain-related raster products…

- Elevation
- Slope
- Aspect

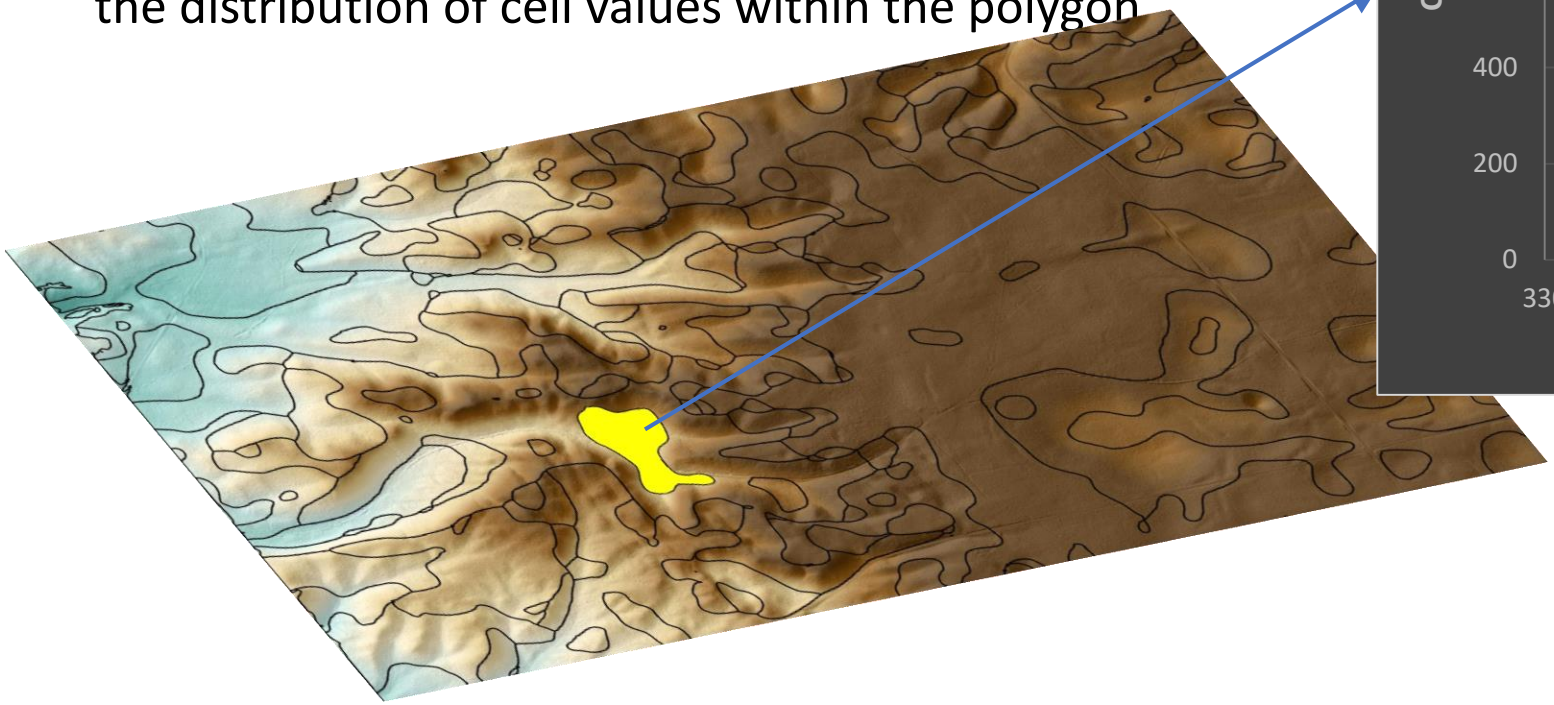


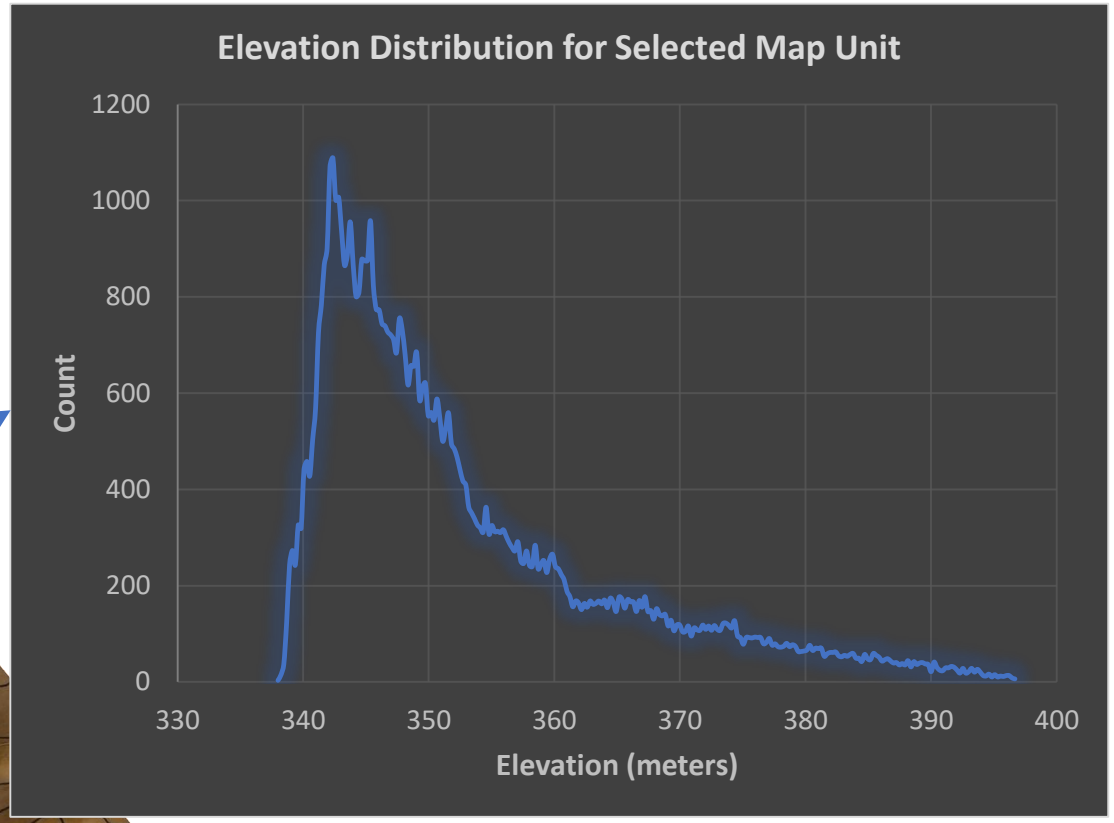
Soils Mapping and Zonal Statistics with LiDAR Data

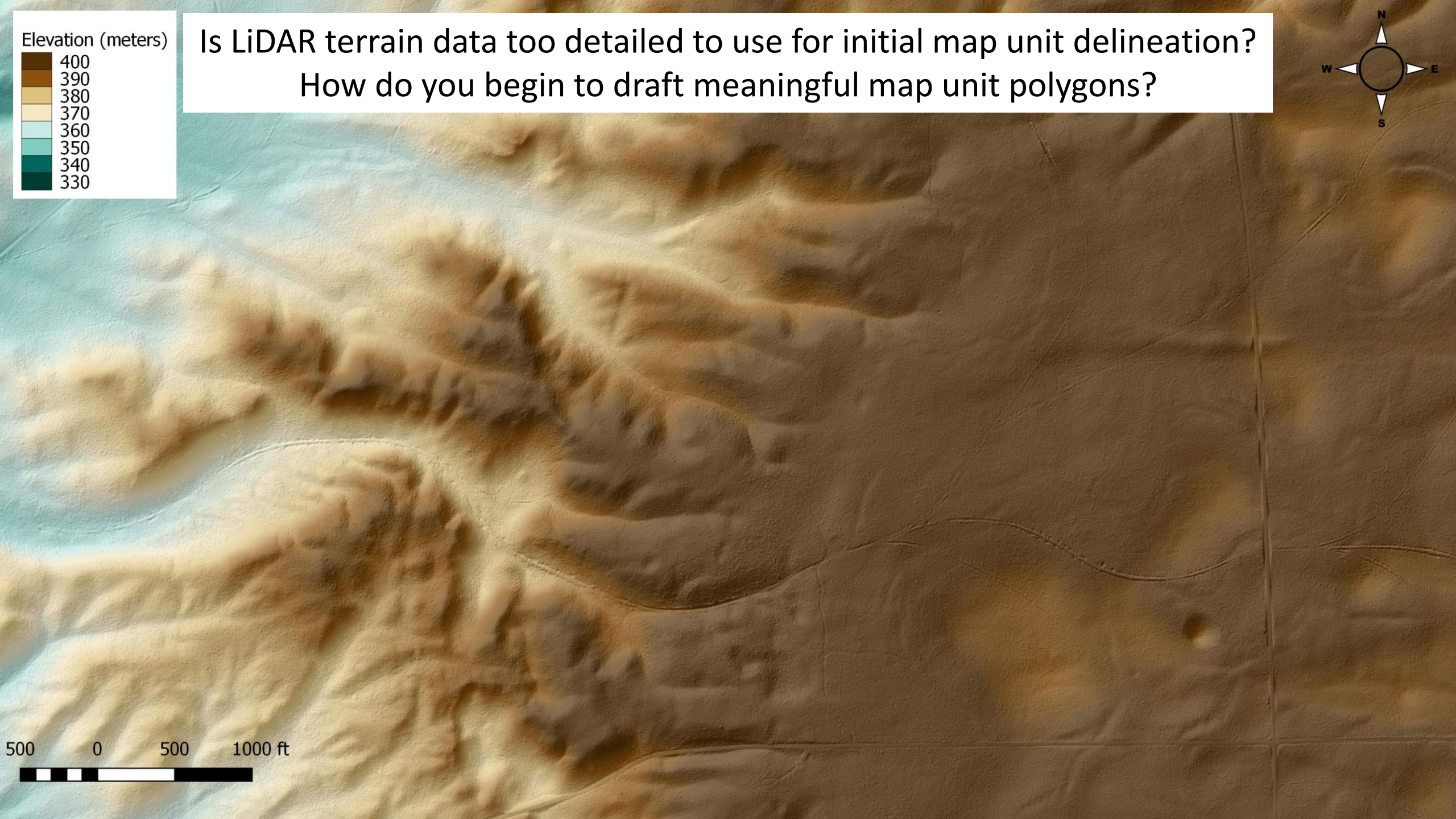
Starting with basic terrain-related raster products…

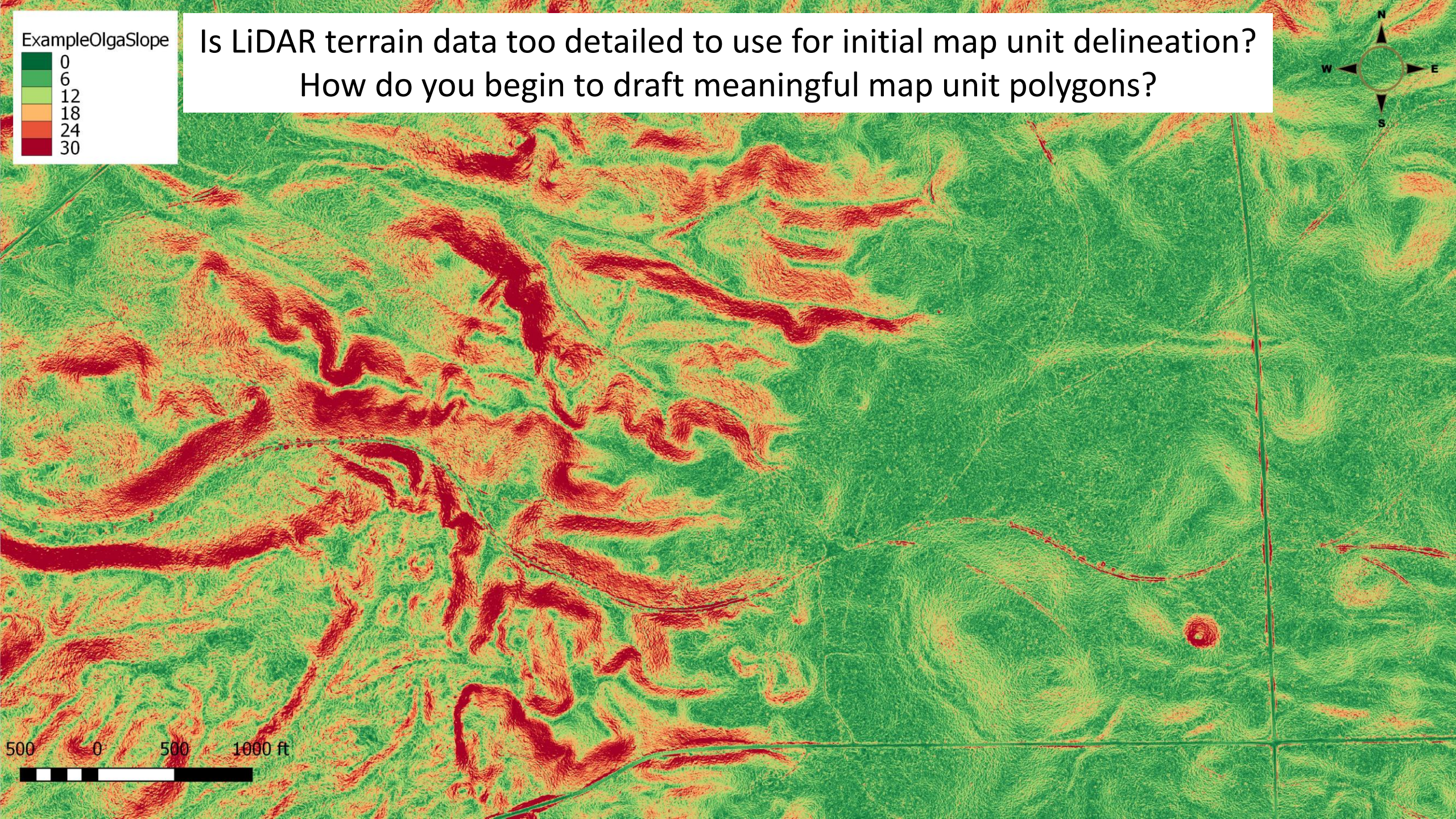
- Elevation
- Slope
- Aspect
- Other raster-based indices?

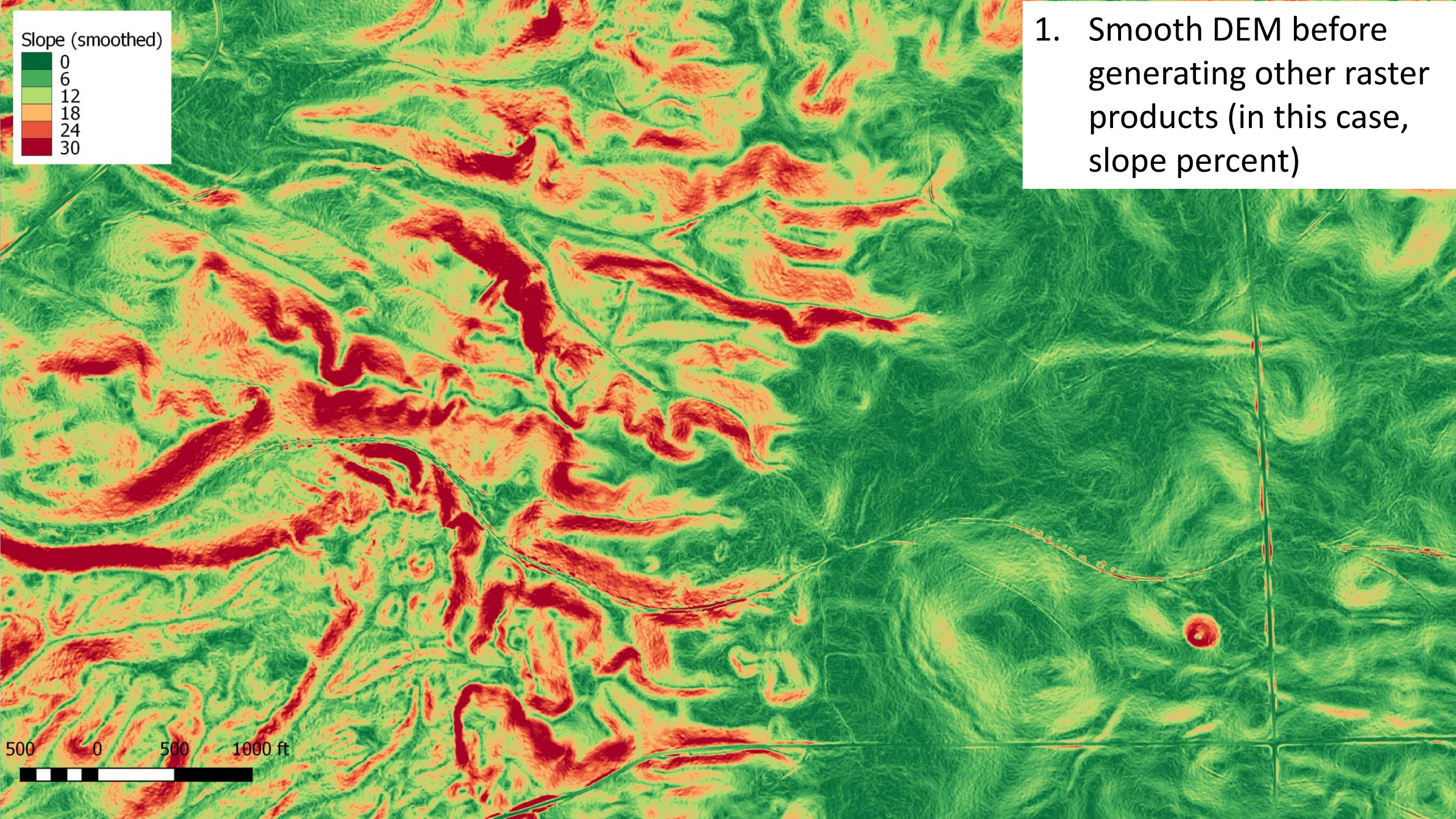
…And overlaying soil map unit polygons to summarize the distribution of cell values within the polygon



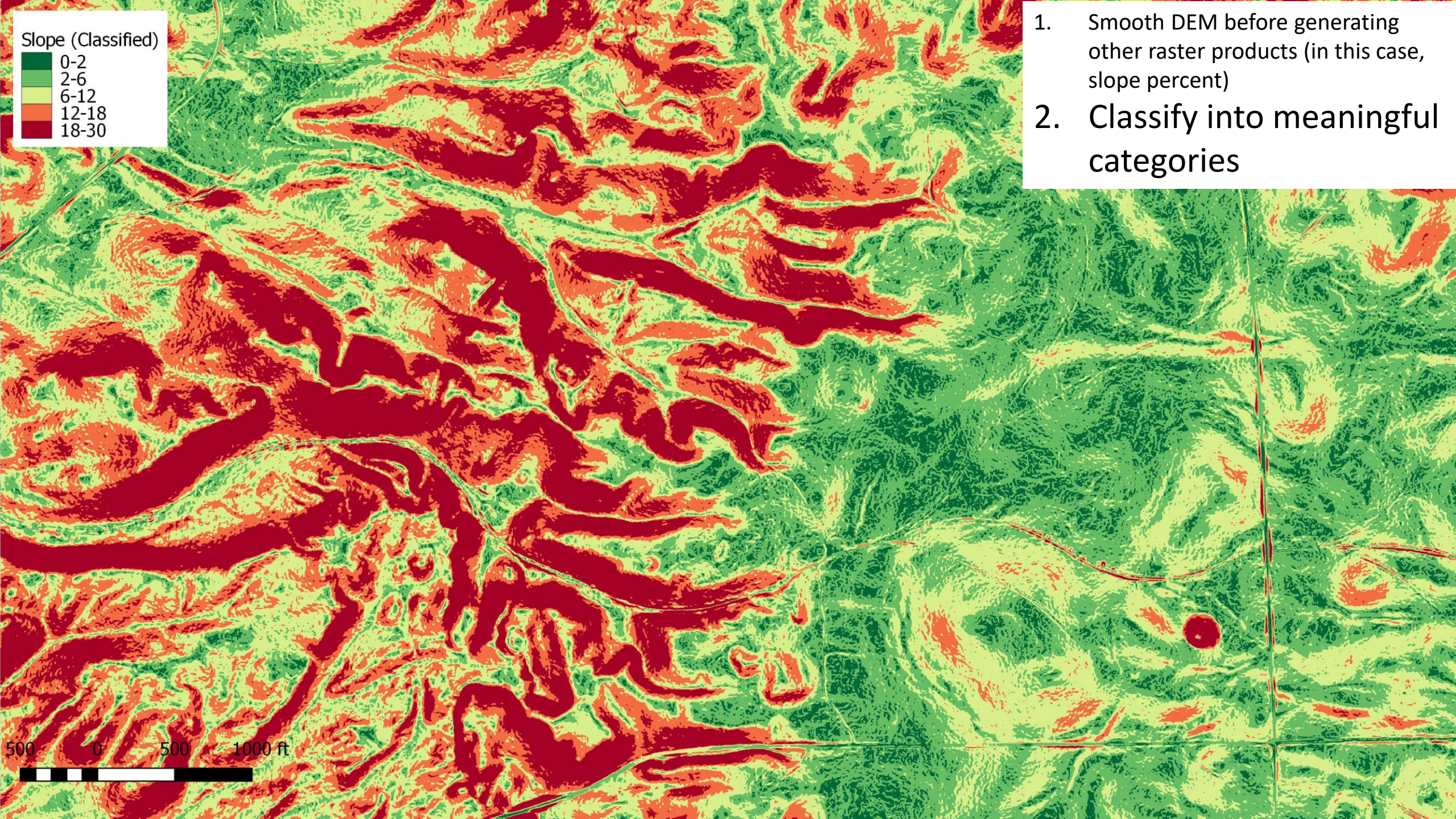



Elevation (meters)
400
390
380
370
360
350
340
330
Is LiDAR terrain data too detailed to use for initial map unit delineation?
How do you begin to draft meaningful map unit polygons?
N
W
E
S
500
0
500
1000 ft

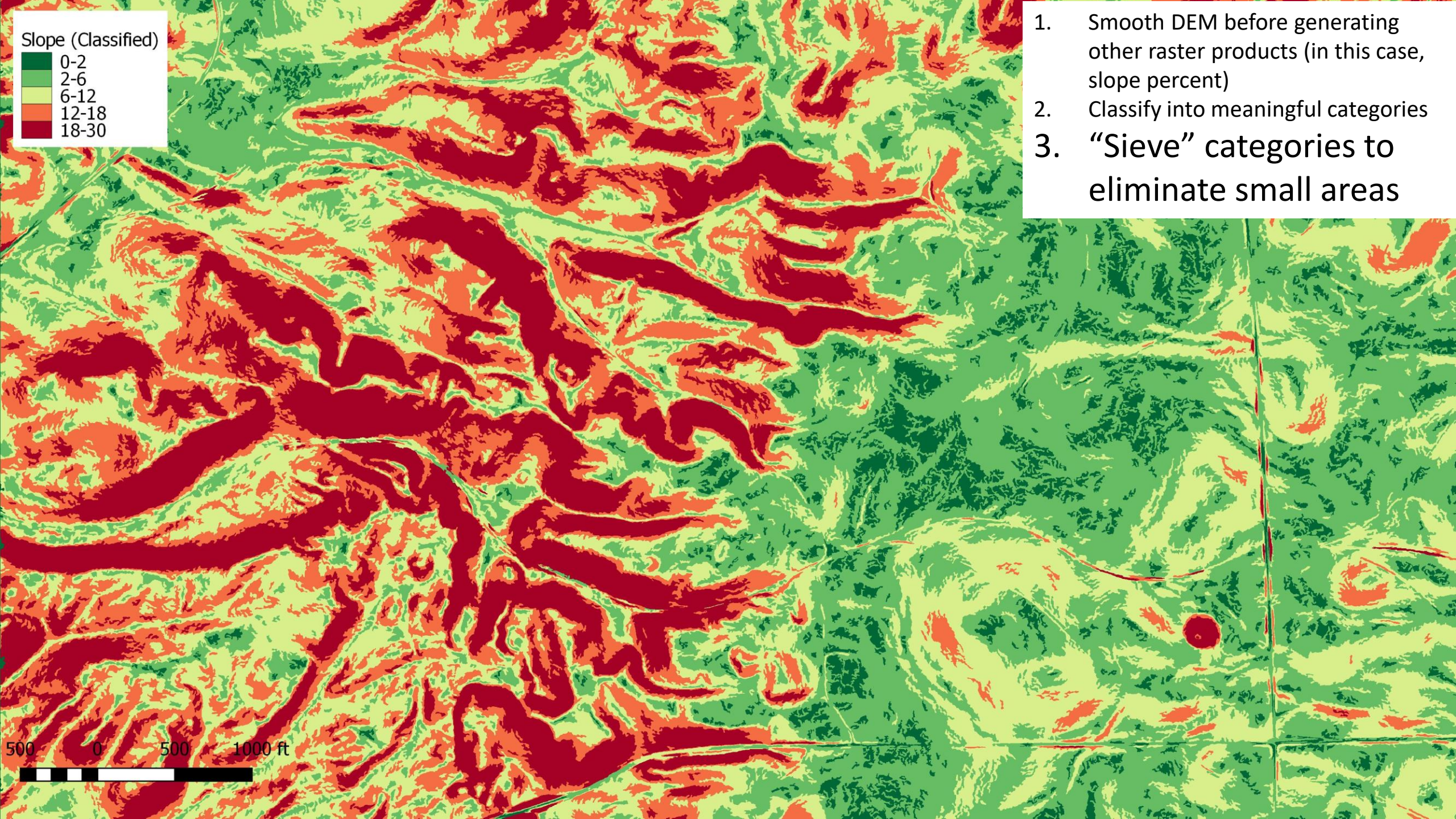

ExampleOlgaSlope
0
6
12
18
24
30
Is LiDAR terrain data too detailed to use for initial map unit delineation?
How do you begin to draft meaningful map unit polygons?
N
W
E
S
500
0
500
1000 ft



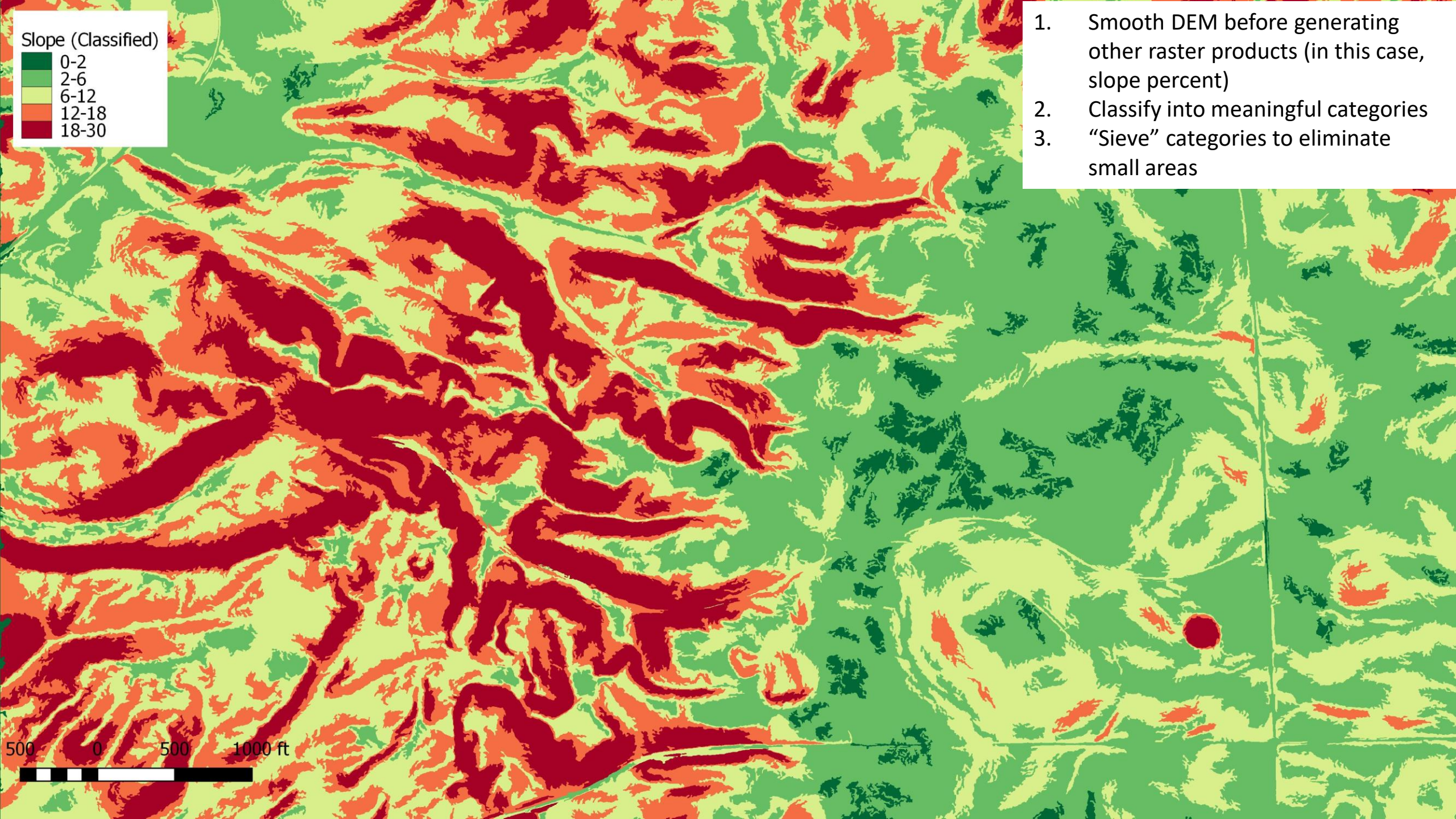
1. Smooth DEM before generating other raster products (in this case, slope percent)



1. Smooth DEM before generating other raster products (in this case, slope percent)
2. Classify into meaningful categories



1. Smooth DEM before generating other raster products (in this case, slope percent)
2. Classify into meaningful categories
3. “Sieve” categories to eliminate small areas



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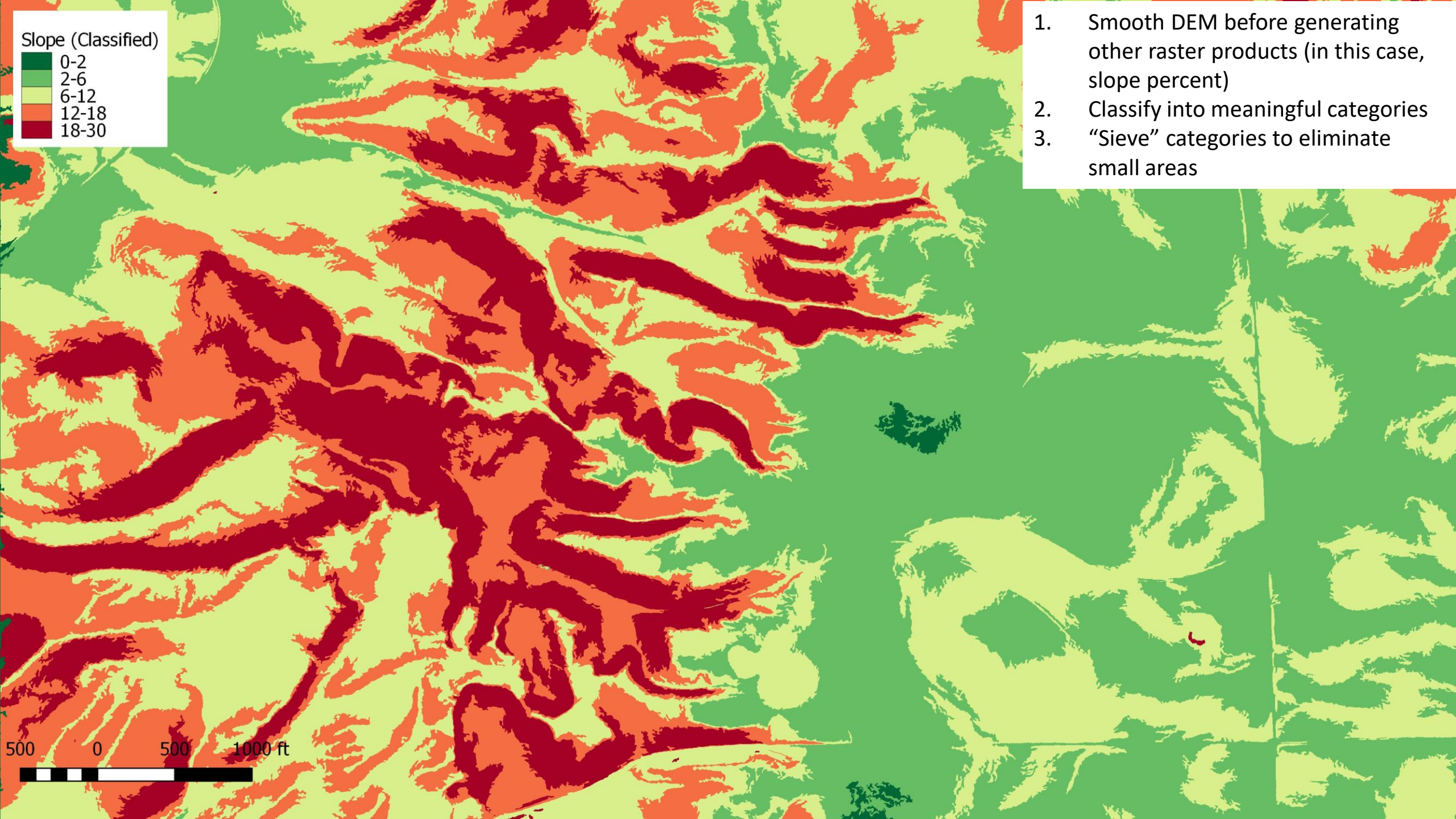

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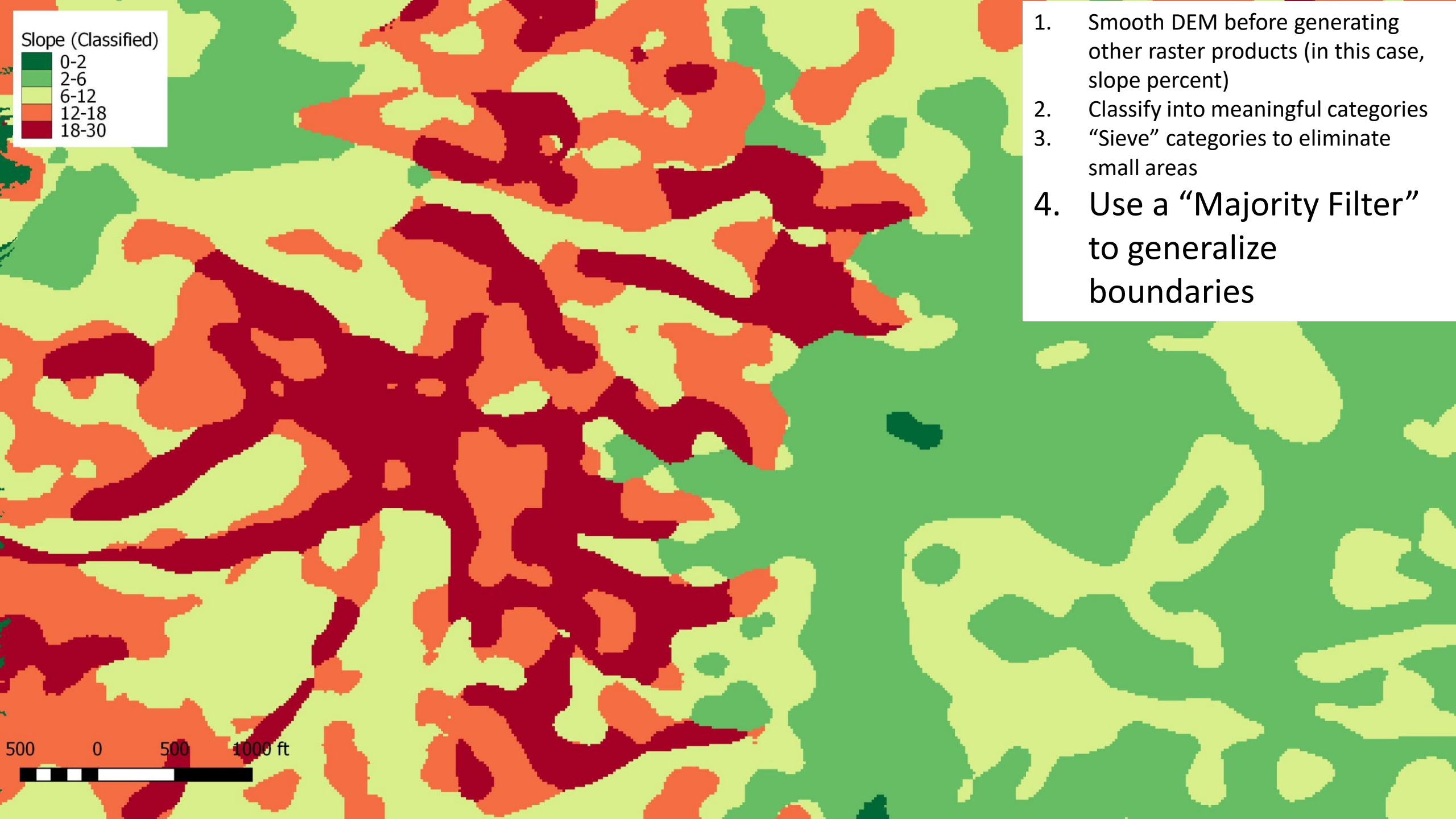
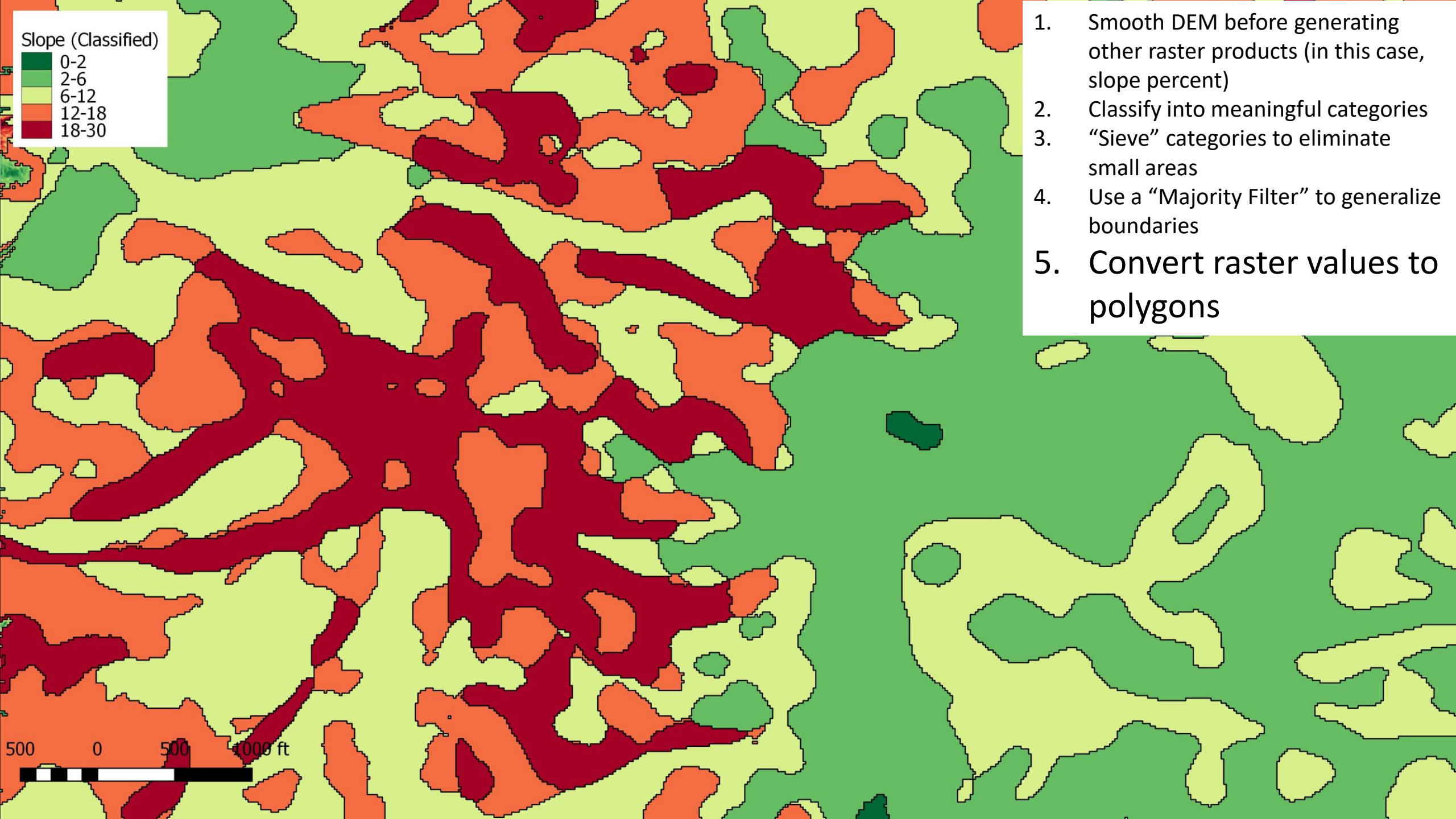
2. Classify into meaningful categories
3. “Sieve” categories to eliminate small areas



1. Smooth DEM before generating other raster products (in this case, slope percent)
2. Classify into meaningful categories
3. “Sieve” categories to eliminate small areas
4. Use a “Majority Filter” to generalize boundaries



1. Smooth DEM before generating other raster products (in this case, slope percent)
2. Classify into meaningful categories
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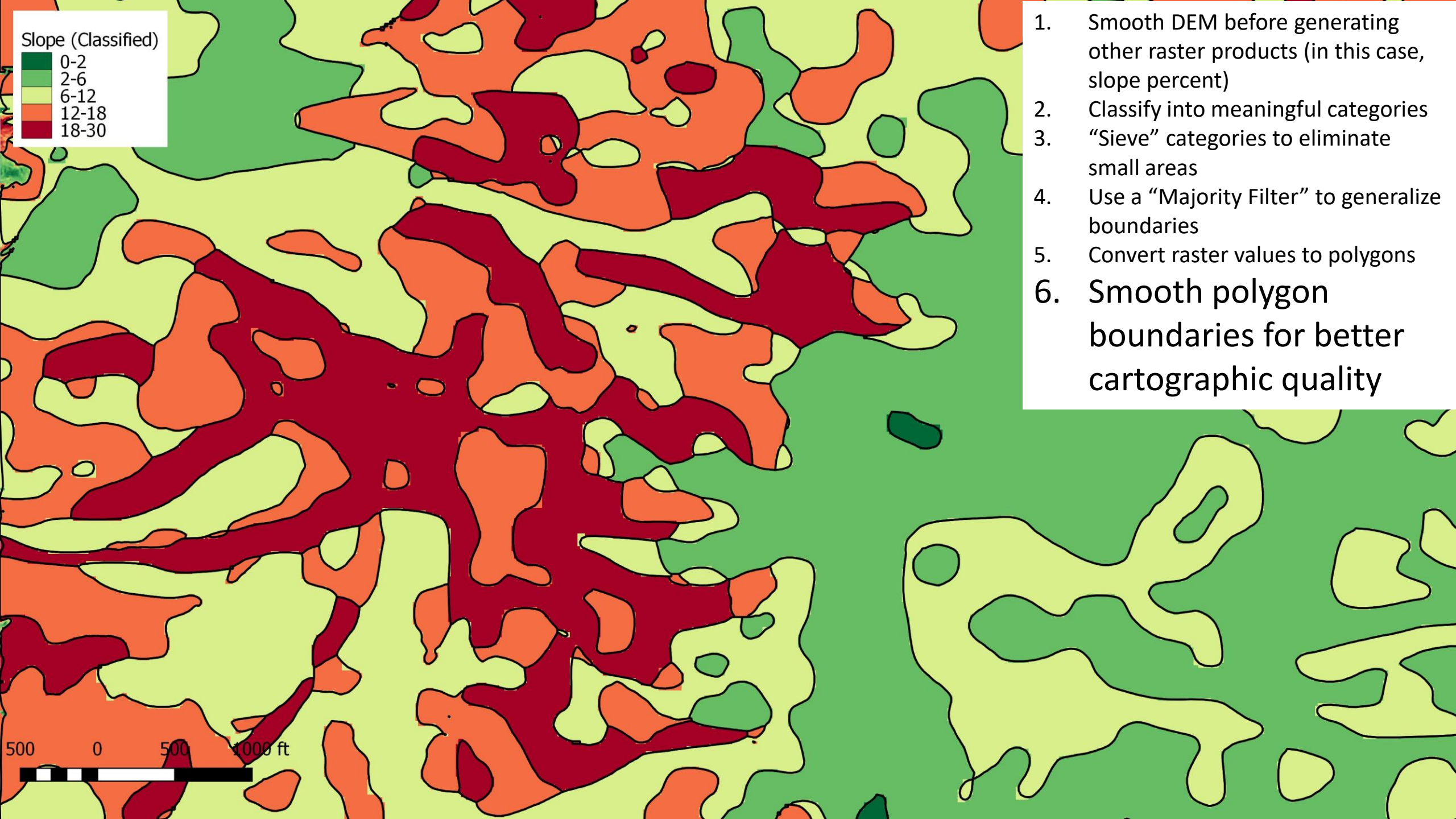
4. Use a “Majority Filter” to generalize boundaries
5. Convert raster values to polygons



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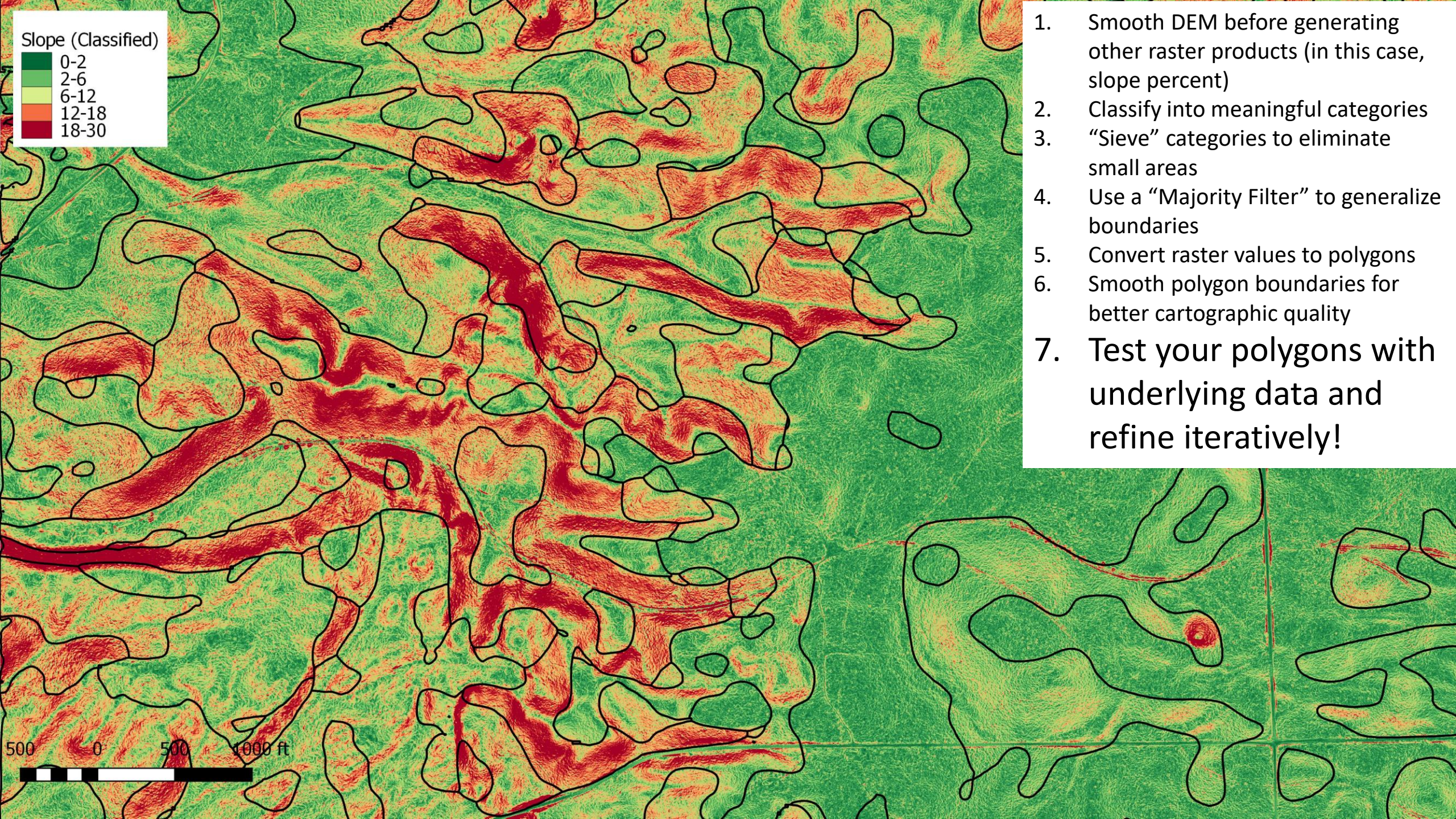
4. Use a “Majority Filter” to generalize boundaries
5. Convert raster values to polygons
6. Smooth polygon boundaries for better cartographic quality



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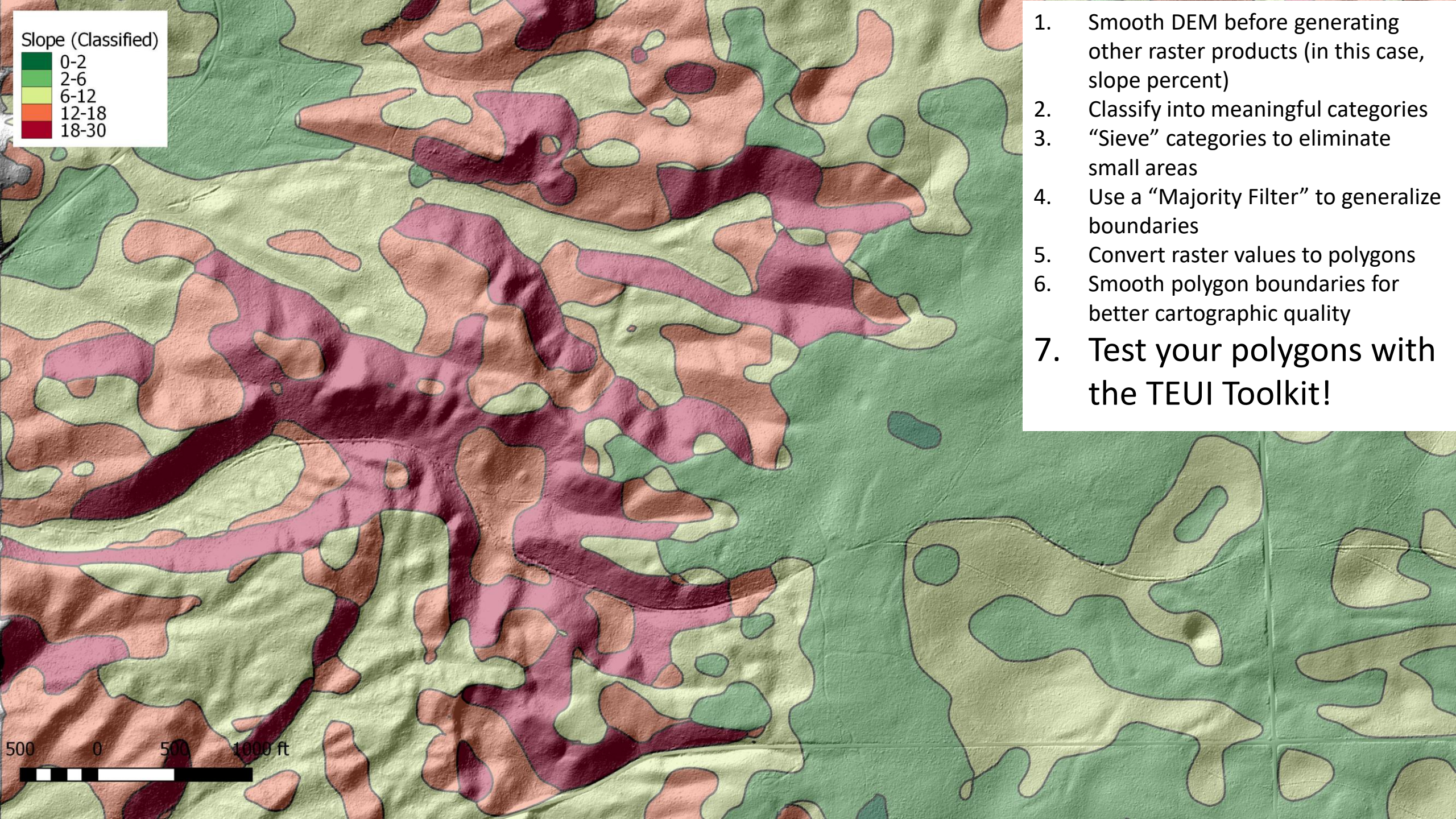
4. Use a “Majority Filter” to generalize boundaries
5. Convert raster values to polygons
6. Smooth polygon boundaries for better cartographic quality
7. Test your polygons with underlying data and refine iteratively!



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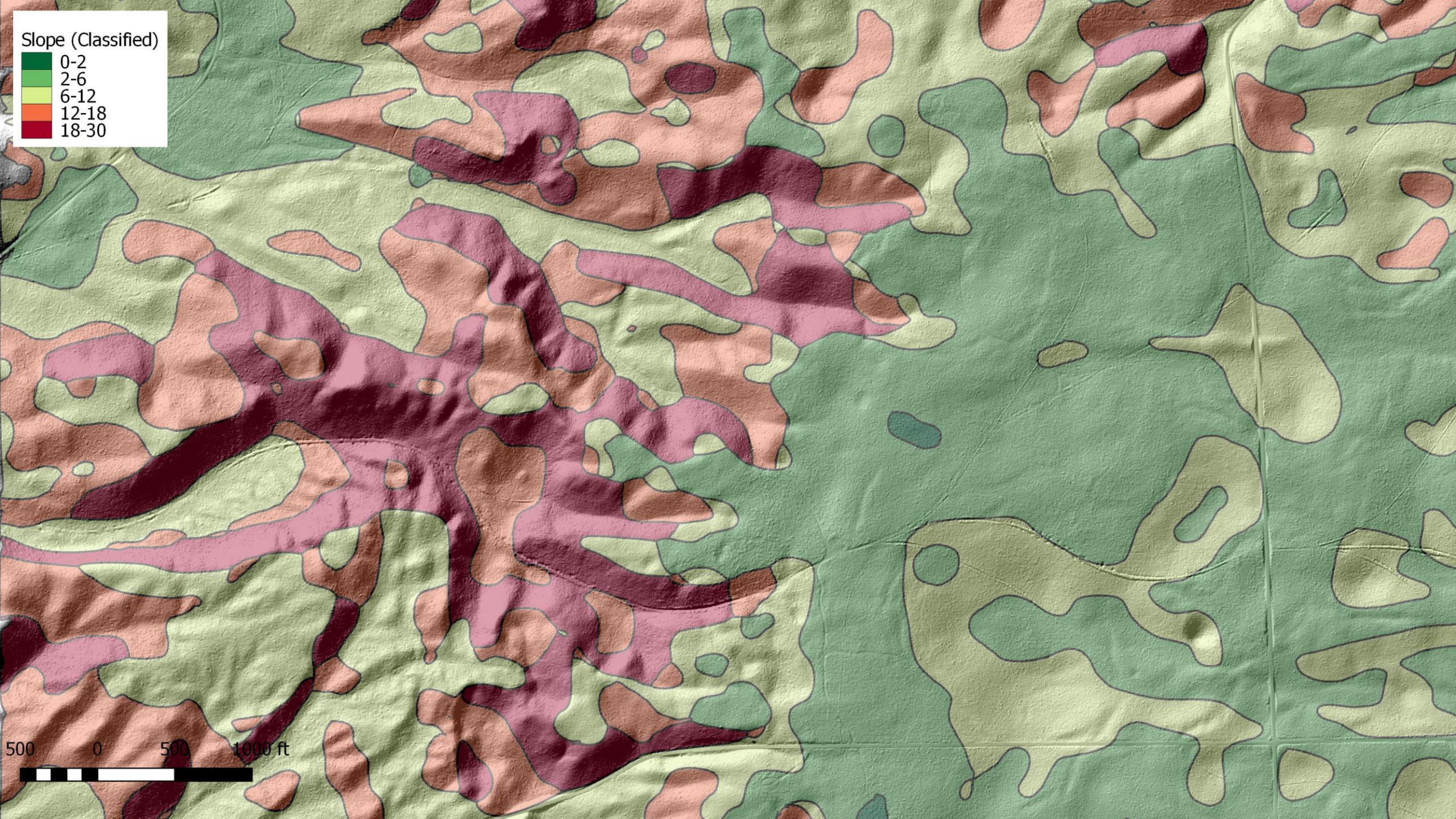
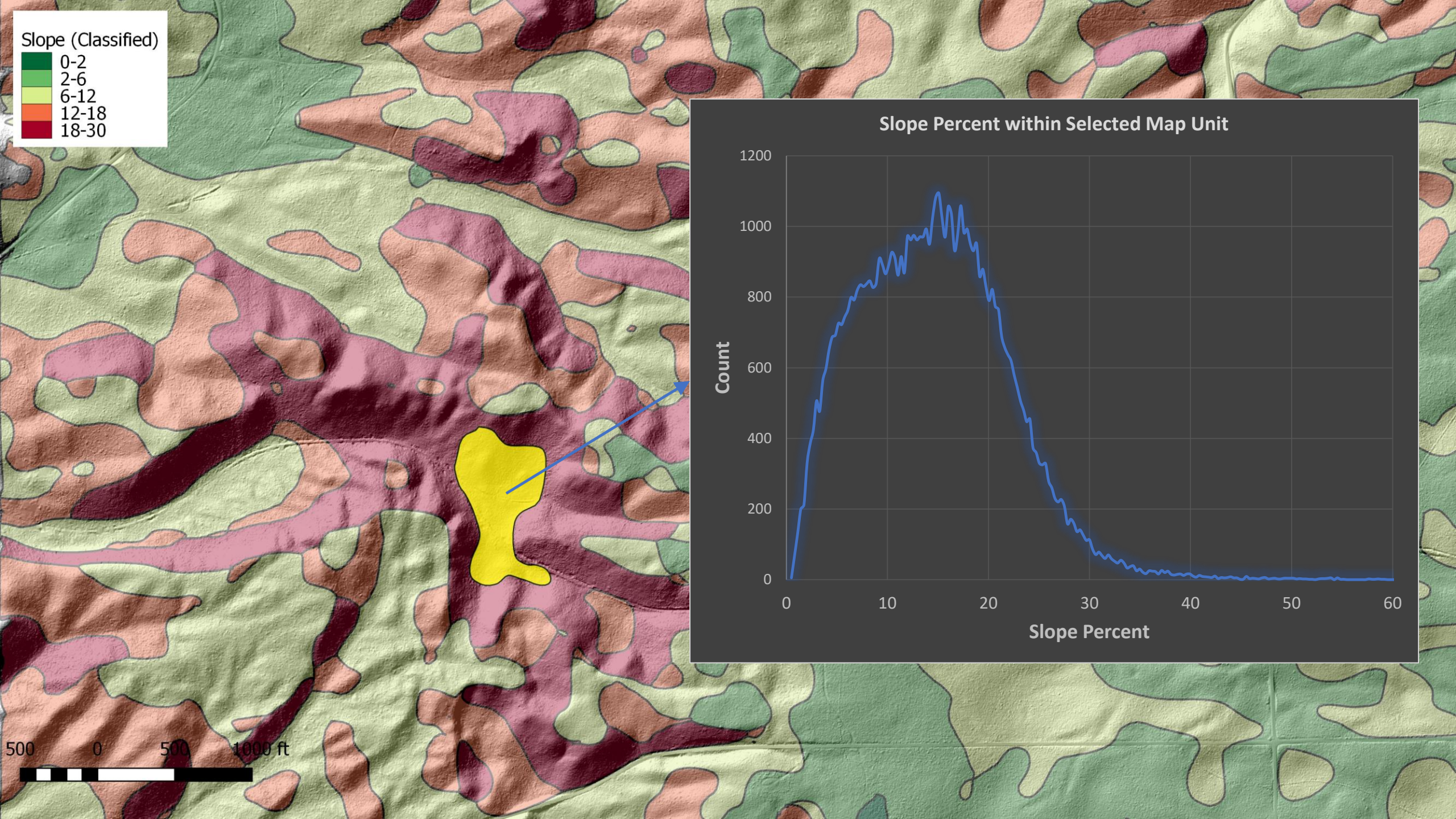
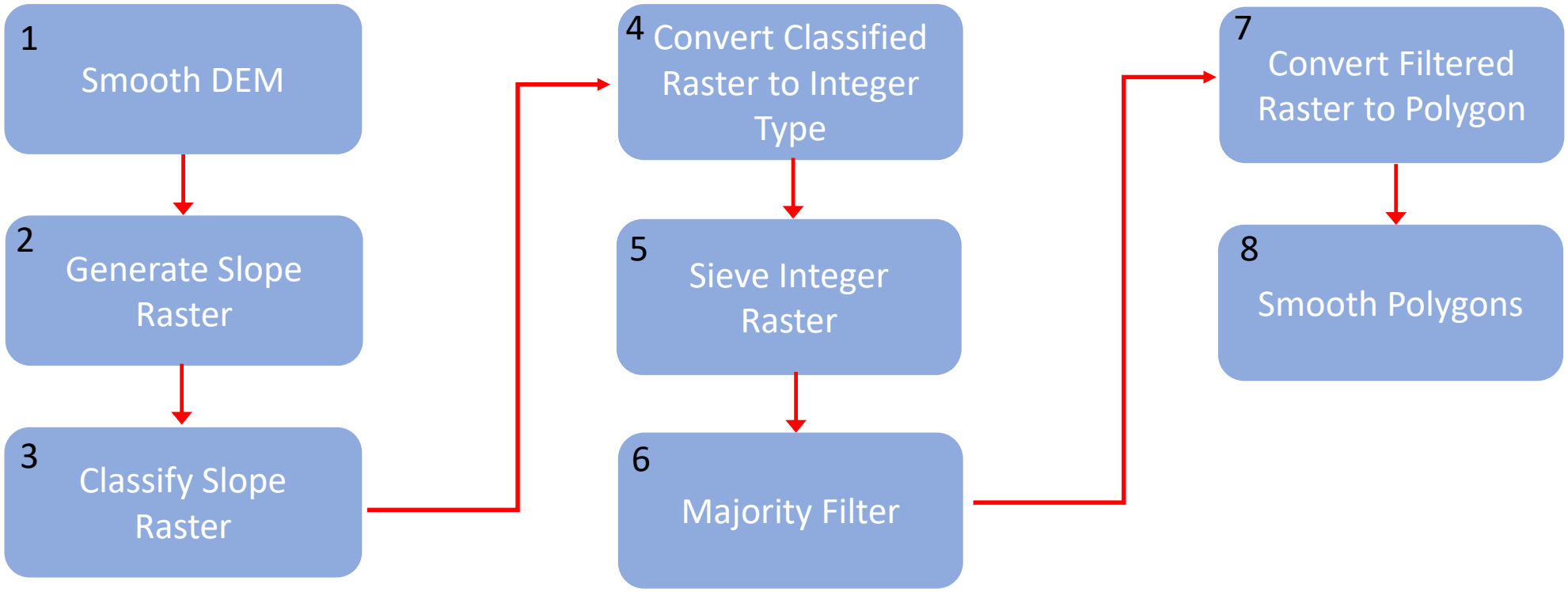
2. Classify into meaningful categories
3. “Sieve” categories to eliminate small areas
4. Use a “Majority Filter” to generalize boundaries
5. Convert raster values to polygons
6. Smooth polygon boundaries for better cartographic quality
7. Test your polygons with the TEUI Toolkit!


Slope (Classified)
0-2
2-6
6-12
12-18
18-30
500
0
500
1000 ft


Slope (Classified)
0-2
2-6
6-12
12-18
18-30
Slope Percent within Selected Map Unit
Count
1200
1000
800
600
400
200
0
0
10
20
30
40
50
60
Slope Percent
500
0
500
1000 ft



Step	Software	Tool / Command	Link to documentation
1. Smooth DEM	SAGA	**Gaussian Filter**	http://www.saga-gis.org/saga_tool_doc/2.3.0/grid_filter_1.html
2. Generate Slope Raster	GDAL	**gdal dem**	http://www.gdal.org/gdaldem.html
3. Classify Slope Raster	SAGA	**Classify**	http://www.saga-gis.org/saga_tool_doc/2.2.1/grid_tools_15.html
4. Convert raster to integer	GDAL	**gdal translate**	http://www.gdal.org/gdal_translate.html
5. Sieve raster	GDAL	**gdal sieve**	http://www.gdal.org/gdal_sieve.html
6. Filter raster	SAGA	**Majority Filter**	http://www.saga-gis.org/saga_tool_doc/2.2.1/grid_filter_6.html
7. Convert raster to polygon	GDAL	**gdal polygonize**	http://www.gdal.org/gdal_polygonize.html
8. Smooth Polygons	GRASS	**v.generalize.smooth**	https://grass.osgeo.org/grass74/manuals/v.generalize.html

- Terrain Analysis - Channels
- Terrain Analysis - Compound Analyses
- Terrain Analysis - Hydrology
- Terrain Analysis - Lighting, Visibility
- Terrain Analysis - Morphometry
- Terrain Analysis - Preprocessing
- Terrain Analysis - Profiles
- Terrain Analysis - Slope Stability

Just one of many free and open source GIS software packages excellent for terrain modeling applications…

SAGA
System for Automated Geoscientific Analyses

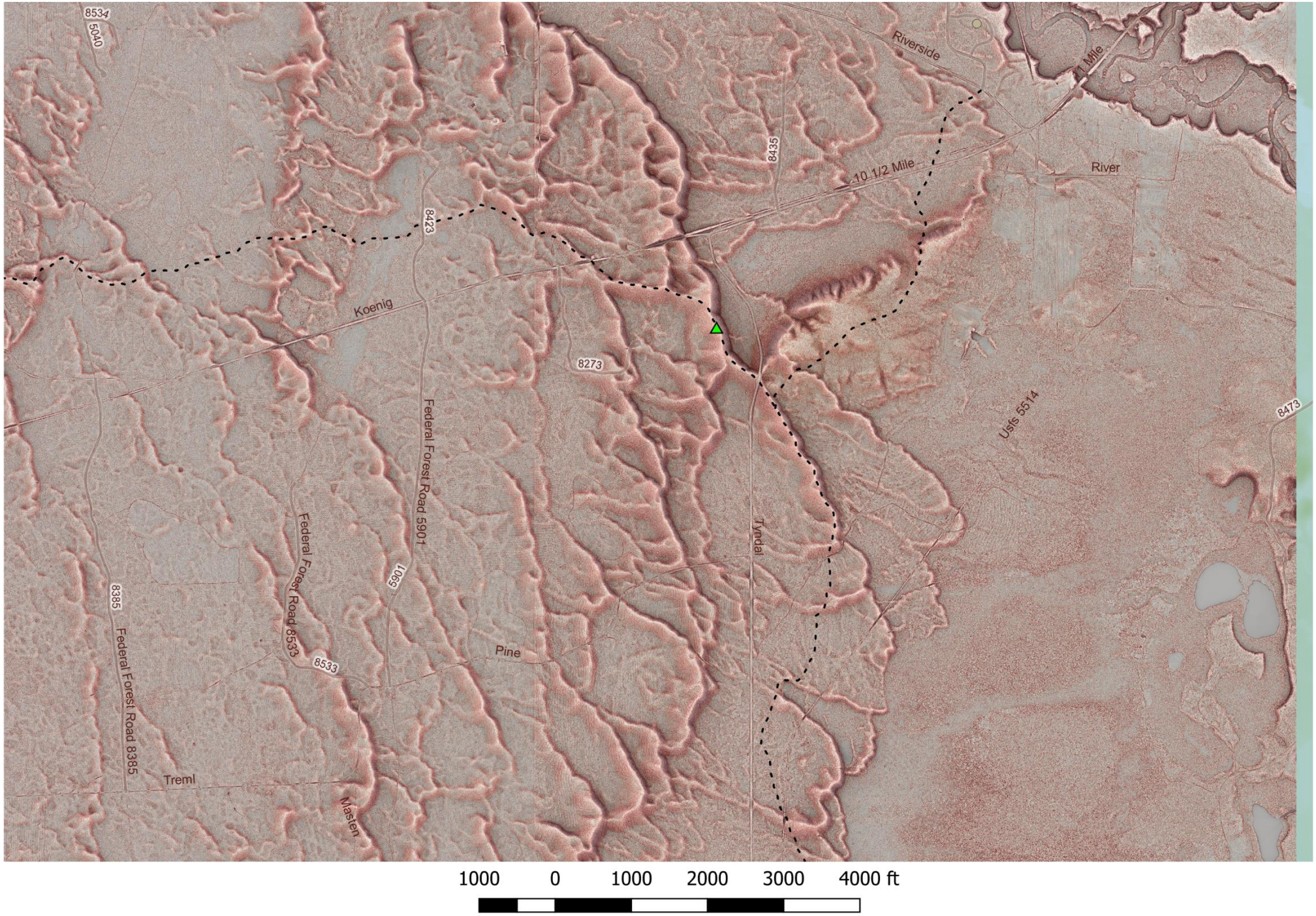
- Terrain Analysis - Morphometry
  - Convergence Index
  - Convergence Index (Search Radius)
  - Curvature Classification
  - Diurnal Anisotropic Heating
  - Downslope Distance Gradient
  - Effective Air Flow Heights
  - Fuzzy Landform Element Classification
  - Hypsometry
  - Land Surface Temperature
  - Mass Balance Index
  - Morphometric Features
  - Morphometric Protection Index
  - Multiresolution Index of Valley Bottom Flatness (MRVBF)
  - Real Surface Area
  - Relative Heights and Slope Positions
  - Slope, Aspect, Curvature
  - Surface Specific Points
  - TPI Based Landform Classification
  - Terrain Ruggedness Index (TRI)
  - Terrain Surface Classification
  - Terrain Surface Convexity
  - Terrain Surface Texture
  - Topographic Position Index (TPI)
  - Valley and Ridge Detection (Top Hat Approach)
  - Vector Ruggedness Measure (VRM)
  - Wind Effect (Windward / Leeward Index)

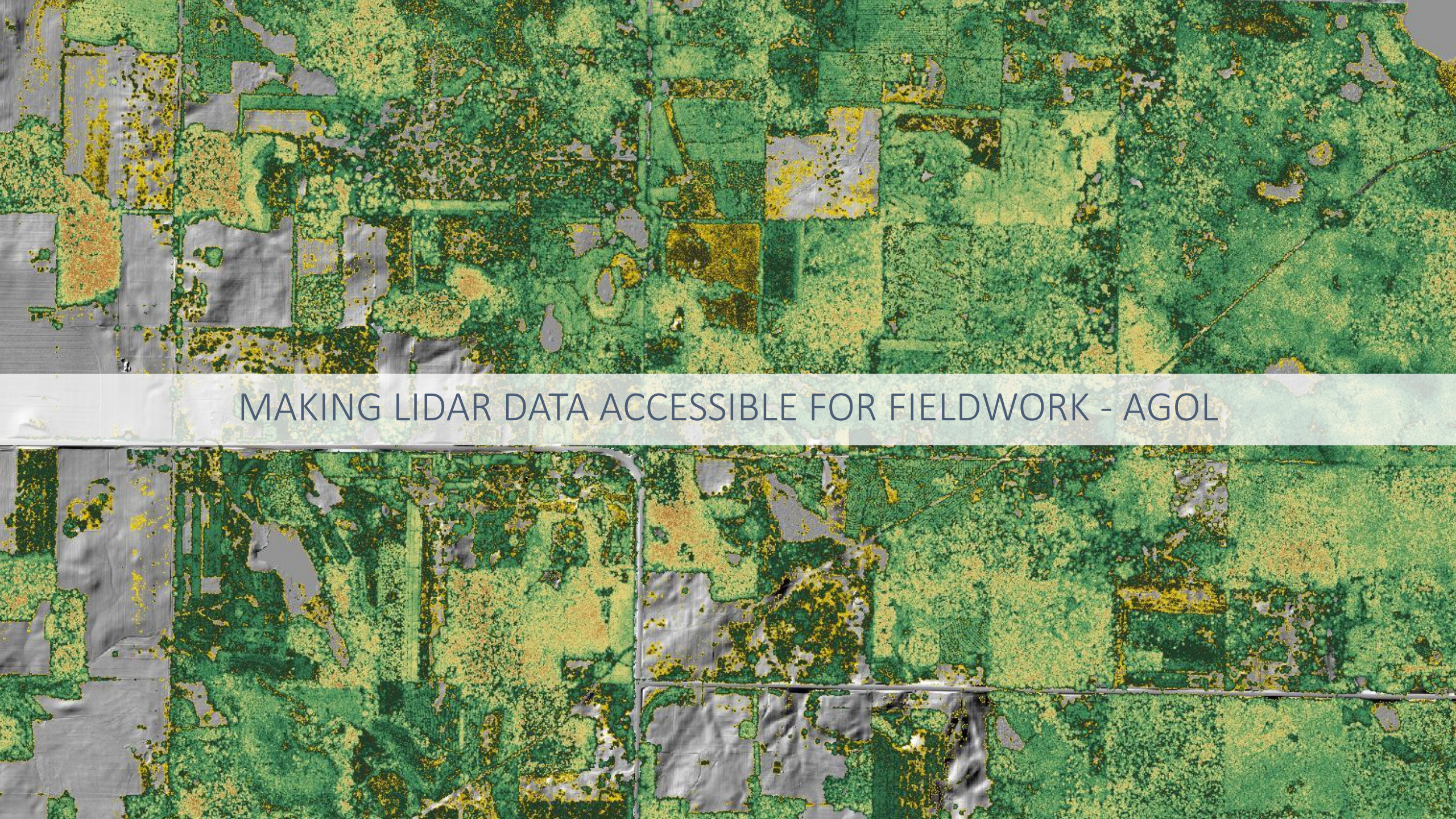
Red Relief Image Mapping

Comprised of…

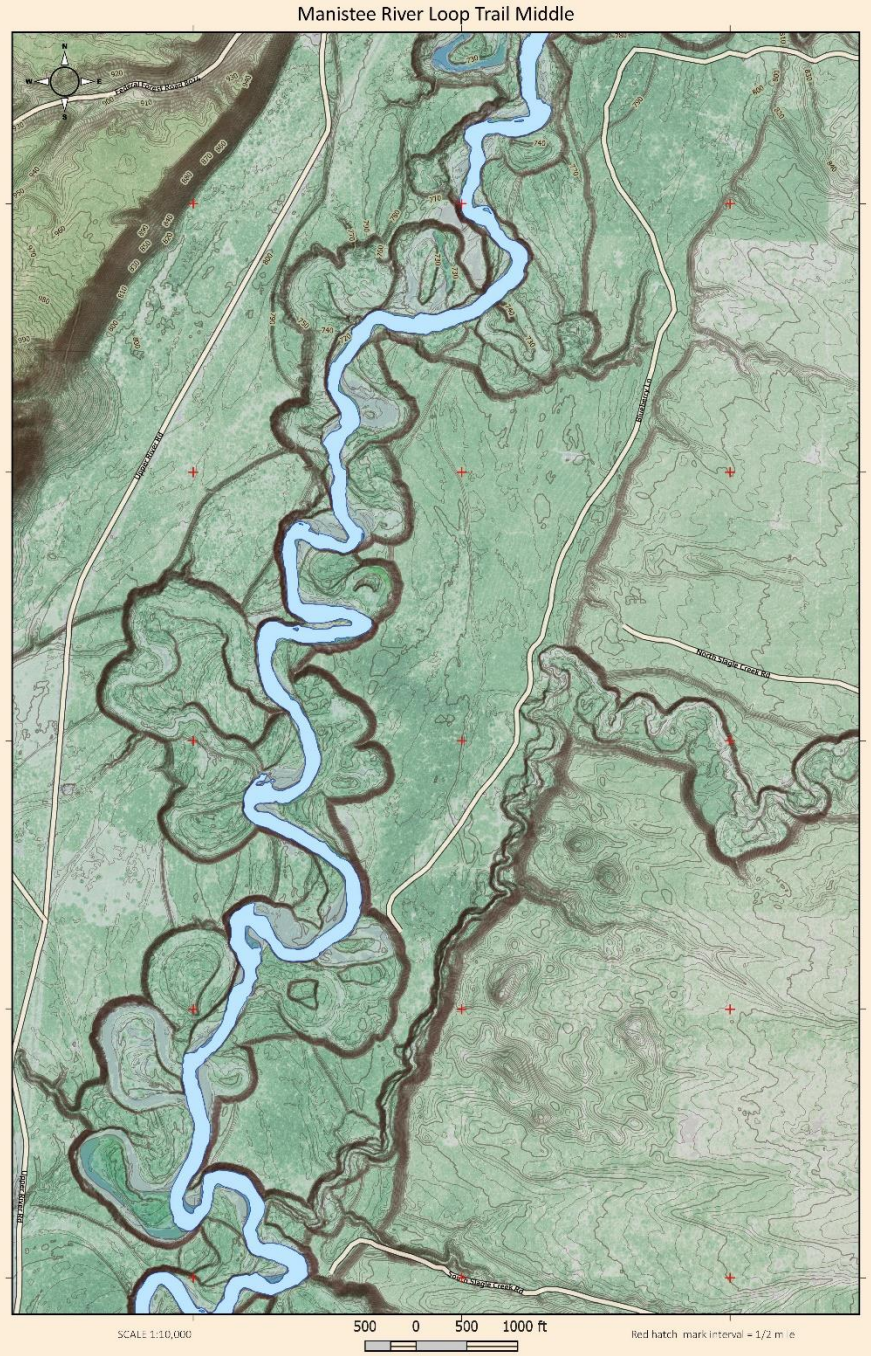
- Topographic Positive Openness
- Topographic Negative Openness
- Slope

Link to learn more…
http://www.isprs.org/proceedings/XXXVII/congress/2_pdf/11_ThS-6/08.pdf





MAKING LIDAR DATA ACCESSIBLE FOR FIELDWORK - AGOL



A 1:10,000 Series for Recreation and Field Navigation

- 2-foot contours (cartographically smoothed)
- Semi-transparent hillshade
- Forest height (above ground level) variable tint
- Breaklines for open-water bodies
- Updated stream delineation

(Work in progress)


Upper River Rd


Upper River Rd

Concluding Thoughts…

- Integrating LiDAR into the NEPA project planning process
- LiDAR as a tool for deeper engagement with the resources we are tasked with managing
- It’s not going to do the work for you, or replace field work- but it will allow you to answer more questions with greater accuracy

Questions?

Thank You!


21N 14W